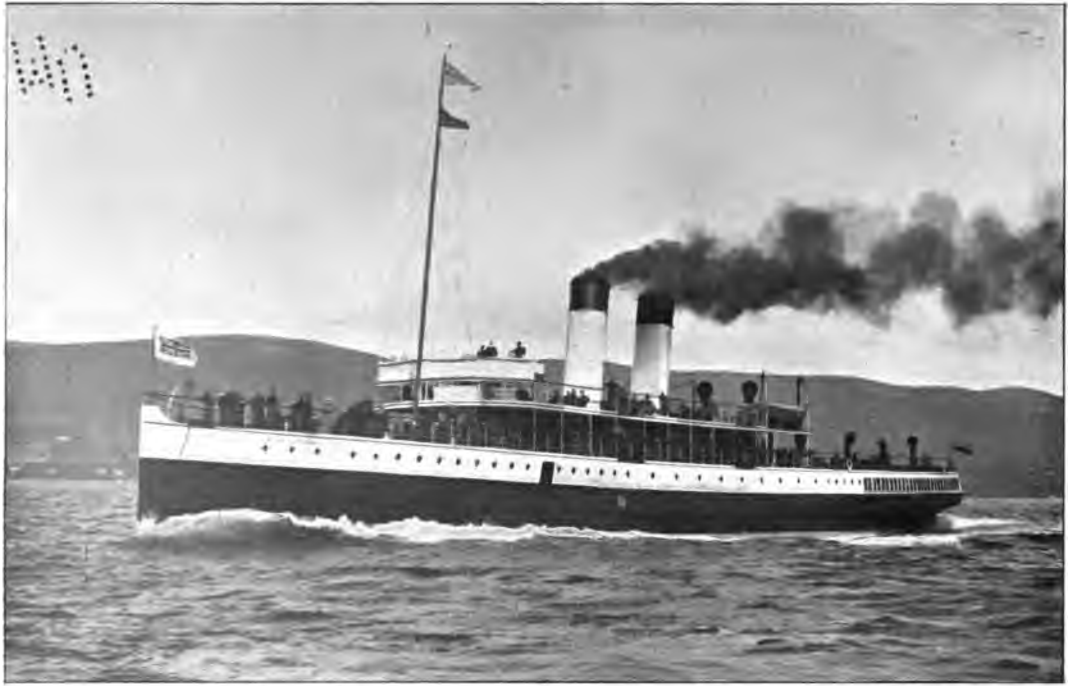

TURBINE CLYDE RIVER STEAMER, "QUEEN ALEXANDRA," BUILT BY MESSRS. WILLIAM DENNY AND BROTHERS, DUMBARTON, AND ENGINED BY MESSRS. THE PARSONS MARINE STEAM TURBINE CO. LTD., WALLSEND, AND MESSRS. DENNY AND CO., DUMBARTON.

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ITS LIGHTS

[illegible] AND PROSPECTS

BY

[illegible] HALDANE, M.INST.MECH.E.

[illegible] MECHANICAL CONSULTING ENGINEER

AUTHOR OF

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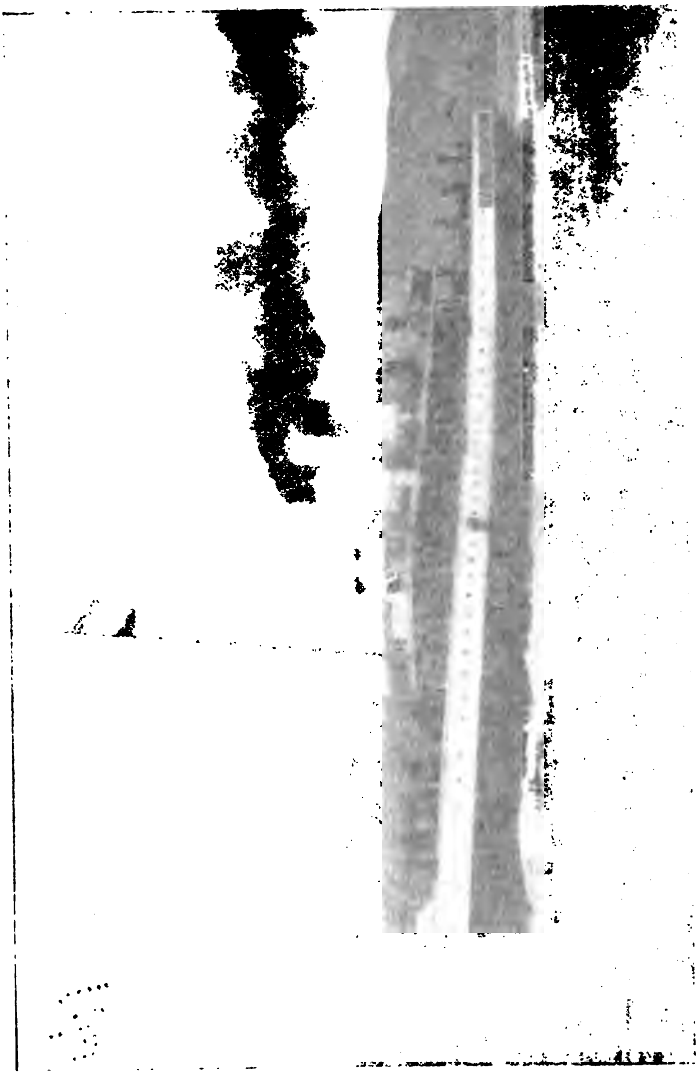

LIFE AS AN ENGINEER

ITS LIGHTS

SHADES AND PROSPECTS

BY

ohn ilton unninghame

J. W. C. HALDANE, M.INST.MECH.E.

CIVIL AND MECHANICAL CONSULTING ENGINEER

AUTHOR OF
"Civil and Mechanical Engineering Popularly Considered;"
"Steamships and their Machinery from First to Last;"
"Railway Engineering—Mechanical and Electrical;"
"3,800 Miles across Canada;" and
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PREFACE.

The highly appreciative manner in which my books on Engineering, and also the popular volume, "3,800 Miles across Canada," have been received, has encouraged me to prepare another, entitled "Life as an Engineer." My object has been to describe as attractively as possible what has been to a large extent my own experiences in the field of Engineering during the last forty-five years. These embrace apprenticeship in the Works, practice in the drawing office and on the designing staff, and in the various occupations of a Consulting Engineer since 1873.

I have specially visited many of the most famous engineering establishments, with the object of obtaining the best and latest information concerning their productions. So that, in the simplest manner, readers of both sexes might be pleasantly introduced to some of the practical methods of carrying out many of the great enterprises which have made travelling on land and sea, and science in general, what they are to-day.

There is much also embodied in the text which may prove useful to engineers, and particularly to youths who intend to

enter the profession, but without knowing what lies before them in its highways and byways. The general scope of the book, however, will be fully gathered from the following "Contents" of the chapters.

It is said of a famous author that he did not mind the truth so long as he could round his sentences elegantly. In this respect, however, engineering literature abounds with so much drily technical phraseology that it is very difficult to write gracefully or attractively—even in a popular volume such as this—or to squeeze a little humour here and there into such a metallic subject.

As general readers do not care to peruse books on any science which are too conventional, I have been compelled not only to write as lightly and brightly as possible, but to adopt the personal style of narrative throughout. Additionally does this appear advisable since many of the best volumes of the practical "Life" order have been those in which the authors thus described their day by day career—"Two Years before the Mast," "Tom Brown's Schooldays," and many others, being excellent examples.

With this explanation in view, I trust I may be excused for adopting the same style of writing, in the hope that, as a labour of love, this treatise may prove acceptable to all classes for whom it is specially intended.

My best thanks are due to those named in the text, who

so kindly allowed me to specially visit their Works; to illustrate some of their machinery; to describe their Processes of Manufacture, and to otherwise obtain from them the best and latest information which, in crystallised form, I have endeavoured to give as expressively as possible in this volume.

J. W. C. H.

65 ANTRIM MANSIONS,
HAVERSTOCK HILL, LONDON, N.W.

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CHAPTER I.

CIVIL ENGINEERING AS IT WAS AND IS.

Comprehensive meaning of the Term — Its various Branches — Examples from Practice—How the Ancients got along without Machinery—Their vast Works—How an 800 ton block of Granite was transported 135 miles—Hero of Alexandria—Archimedes—Their Mechanical Genius—Why Engineering so long remained a Dead Science — Euclid — Great Tunnels of To-day — Piercing flinty Rock for 12 miles — How accomplished—Bridge Engineering—Romance of Science—Drainage and Reclamation of Land on a prodigious scale — Gigantic Pumping Operations—Drainage of the Zuyder Zee—Unlimited Mechanical Resources of Modern Times—Their effect upon the World.

THE term "Civil Engineering" has an extremely comprehensive meaning, and although popularly but erroneously supposed to refer only to the construction of railways, harbours, docks, canals, and river improvements, and so on, where brick, stone, earth, concrete, timber, etc., are the chief materials, it nevertheless includes amongst its numerous branches that of Mechanical Engineering, in its endless phases and infinite variety of applications in the world of practical science. The term "*Civil* Engineer," in fact, implies an engineer who does *not* belong to the military service. Let me, however, describe it in detail, as officially given in the Records of the Institution.

The practitioners in this science have to do with the following classes of work, at home or abroad:—

1. Works for facilitating and improving internal communications—as roads, railways, tramways, navigation by canals and rivers, bridges, and telegraphs of various kinds.

2. Works connected with the sea-coast, and for facilitating communication between the sea and the land, such as harbours, docks, piers, breakwaters, sea-walls, lighthouses, etc.

3. Works for facilitating communication across the seas, including naval architecture, iron-shipbuilding, and the construction and laying of submarine telegraph cables.

4. Works for the reclamation, irrigation, or drainage of land; and for the prevention or the regulation of floods, including the improvement of rivers, as arterial drains.

5. Works for cities and towns, such as sewerage, water supply, lighting, and street improvement.

6. Large and massive buildings generally, in their scientific and mechanical arrangements.

7. The operations of mining and of metallurgy, so far as they involve the application of mechanical science.

8. The design and construction of the mechanical prime movers, such as steam engines, water-wheels and other hydraulic motors, windmills, electric and other engines.

9. The design, construction, and adaptation to practical use of machinery and mechanical appliances of all kinds.

10. The design and manufacture generally of all large and important metallic structures, including artillery, and other munitions of war.

This description gives, in the main, a graphic outline of the leading features of the profession referred to, but does not in any way indicate their minute and endless subdivisions of the present. The origin of the science in its most primitive form dates back some thousands of years. Men very early discovered the art of making iron, and brass and steel, and of casting the two former into complex and sometimes colossal forms. They also found out, in ancient Egypt, ways and means of cutting out of quarries immense blocks of granite, over 100 tons in weight, and not only transporting them long distances, but lifting them to great heights, as in the Pyramids, and in gigantic temples, etc. A wonderful example of this is to be found in the great Temple of Rameses the Second, which contains a colossal statue of that king, which was carved out of a single block of red granite weighing 887 tons, and transported from the quarries at Assouan, 135 miles distant.

These operations long proved inexplicable, but we now know that the means employed were of the simplest nature, and worthy of imitation in out-of-the-way parts of the world to day. The wonderful deeds referred to were performed by means of levers, wedges, and variously constructed inclined planes up which the load to be transported was carried on segments of trees, used as rollers, aided by the sheer force of multitudes of slaves. Excellent examples of the application of inclined planes are to be found in some of our large quarries, and also on railways in mountain regions.

A fine specimen of one of the latter I have traversed on the Canadian Pacific Railway, between Trail and Rossland, British Columbia. Here, for about a mile of *direct* distance, the descent is so severe and confined in area that a series of zig-zag inclines, *without bends*, are employed, and on these the train is run backwards and forwards until either the high or the low level is reached.

Amongst those who flourished in ancient Greece were three very remarkable men. One was Hero, of Alexandria, another was Archimedes, and a third was Euclid. The two former touched the very borders of our system of mechanical engineering, but were unable to develop their ideas sufficiently on the subject.

Hero flourished about 130 B.C., and his extremely primitive "Æolipile" was almost identical in principle with the "Barker's Mill" of our own time. He also employed steam as an agent in giving life-like and apparently heaven-inspired actions to the gods of the period, and thus deluded their worshippers.

A writer in the *Quarterly Review* observes that:—

> Archimedes was a profound genius who drew from his intellectual treasury a rich store of the most curious theoretical discoveries, and of the most useful practical inventions. He maintained a rank among the ancient philosophers similar to that of Newton amongst the moderns. He may also be considered the father of the science of statics and hydrostatics, for to him we owe the true theory of the equilibrium of forces in machines, and also in the pressure of fluids. He understood the

theory of optics, as is evident from his invention of the burning mirrors, by means of which he set fire to the Roman fleet at a furlong's distance. His discoveries in pure geometry alone would secure for him the admiration of all ages, as he travelled in so many unbeaten paths, and adopted methods to aid him in his investigations which were so admirable, that antiquity has assigned him the first place among geometricians.

Archimedes had a mind so exalted that, in accordance with the ideas of the Platonists, he would not condescend to leave behind him any writings upon engineering and the useful arts, preferring rather to immortalise, in his various treatises, the sublimely intellectual science of pure mathematics in which he was so profound.

Thus we have a distinct reason given for the practical application of steam remaining a dead science throughout all those centuries until James Watt arose, and, with a few master-strokes of genius, laid the foundation of its present world-wide extension in ten thousand and one different forms.

We cannot now learn much more of the history of Euclid than is generally known. Those, however, who have studied *his* science must be fully aware that it is the only exact one we possess, and one which is entirely free of all such terms as "very near," "just about," and so on. Besides this, there is such variety in Euclid's problems and theorems, and so much practical benefit to be derived from them, that they become invaluable to those who need their aid in many ways,

frequently, too, in ways absolutely unattainable by any other science.

Civil engineering as it was, and as it is, are two very different things indeed. When railways in large numbers had to be constructed; when canals were greatly in demand; when the road system throughout the country was being developed; and when, in these three cases, an immense amount of highly skilled labour was required, and few in the land possessed the requisite experience, engineers prospered greatly. Now, however, Great Britain has become so overrun with railways, roads, and canals, that there is not much left to be done at home in this direction. On the other hand, so enormous is the demand for similar undertakings in foreign countries, and so extensive are the resources of modern civilisation, that a bright future appears to be still in store for the engineering profession in all its branches, especially electrical.

Since the Manchester Ship Canal was completed, other gigantic projects of a similar nature have been brought forward from time to time, and are now in progress. The most prominent of them, however, are now so well known that comment is needless.

Another branch of Civil Engineering that has been wonderfully developed in later years is the science of tunnelling, which even yet appears capable of great extension. The Mont Cenis and St. Gothard tunnels were great undertakings, but they sink into insignific-

ance when compared with that of the Simplon recently completed, after enormous and numerous difficulties had been successfully overcome, which, at the first, deterred many from entering upon the work. Not only was the length of the proposed tunnel unusually great, and the rock in many places extremely hard, but people were afraid that the high temperature in the middle, combined with foul air, would render the interior unworkable. Mr. Brandt, however, astonished the world when it became known that he had offered to cut this tunnel, twelve miles long, not only for less cost than that through the St. Gothard mountain, but in half the time, or five-and-a-half years.

This was owing to the fact that the former was to consist of *two* parallel tunnels having cross connections with each other, by means of which good ventilation would be assured. Secondly, the system of drilling and blasting was to be as near perfection as well-tried experience could make it. And, thirdly, every appliance which modern science could suggest was to be brought into play to facilitate operations to the utmost.

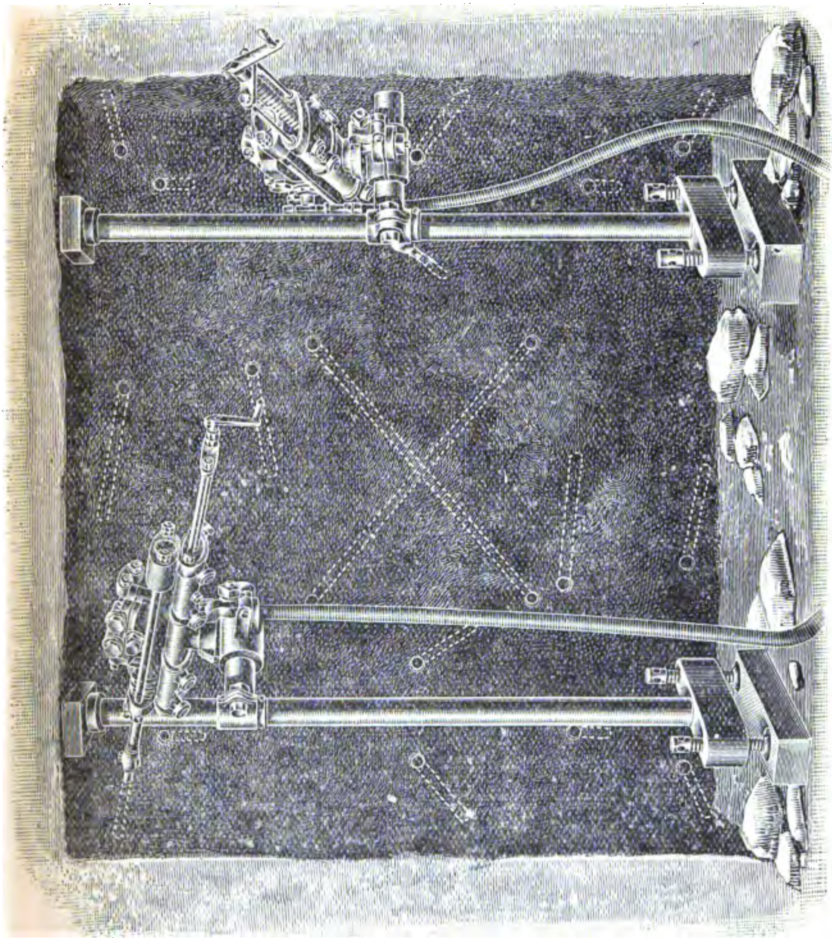
A view of one of these appliances for mining or tunnelling purposes, by Messrs. A. & Z. Daw, of London, is given on page 9. From this it will be seen that, by means of the swivelling and sliding arm on the vertical bar, the machine can drill holes in any required direction, the drill being fed forward by the attendant who revolves the feed screw by its handle. When the holes are bored in sufficient number to ensure

the desired result, electrical firing of the blasting charges performs the rest, either in the form of rock excavating, as shown, or for mere stone block quarrying purposes.

In general practice, the 60 pound per square inch compressed air cylinder ranges from $2\frac{1}{4}''$ to $3\frac{1}{2}''$ diameter, the drills being made to suit $2''$ to $3''$ diameter holes from 6 feet to 20 feet in depth. Their cutting edges are of chisel, **X** or **Z** shape, according to the nature of the material operated upon. A $3''$ cylinder machine delivers from 500 to 700 blows per minute, and as, at each stroke, the drill slightly revolves, the rock is progressively pulverised to the end, the released air usefully ventilating the tunnel.

This invaluable machine, of which there are various arrangements, is insignificant when compared with those of Titanic build described elsewhere, nevertheless, without its aid, some of the most colossal works of modern times would be prohibitively expensive to construct. It may be added that electricity is also used as a motive power when desired.

Civil engineering also includes the designing and construction of bridges in timber, iron, brick, and stone, and there is probably no kind of structure in which more ingenuity and fertility of resource have been needed than in those which cross rivers, ravines, etc., requiring in most instances to be specially adapted to meet the ever-varying conditions of site, locality, width of span, and loads to be carried, such as those which are



COMPRESSED AIR ROCK DRILLING MACHINES.

created by railway, road, or foot-passenger traffic, and we may also add the caprice, practical considerations, and taste of the designer or promoter.

In countries such as England, which abounds in rivers, bridges are invaluable. So long as the population was limited, intercourse between one place and another was of the most primitive nature, hence there did not exist any necessity for our modern methods of sustaining the continuity of the roads or tracks which then prevailed. The shallow parts of rivers were naturally selected as the proper places for fords, which could easily be waded by men and horses when the water was low, and even in times of flood might be crossed by swimming.

Towns and villages sprung up at these localities, from which they derived their names, such as Dept*ford*—"deep ford" originally—Dart*ford*, Ox*ford*, and so on, and in course of time the civil engineer was called upon to design and erect the much-desired bridges, which in many instances are to this day lasting records of his skill.

Between the simplest and most primitive form of bridge, consisting of a piece of timber spanning a small stream, and the colossal structure on the Forth, there is, indeed, a very wide gulf, and between these two extremes, bridges are to be found in endless variety, and involving considerations of the most diversified character. A plank thrown across a ditch may cost a few pence, and if it should break in the middle with a

passing load, the damage will be insignificant; but if, on the other hand, a structure such as the Britannia Bridge across the Menai Straits, or that across the Niagara, were to give way while a train was passing over it, the rolling stock and all it contained would be annihilated, and one country at once become severed from another, so far as the local traffic was concerned. Thus the importance of high-class bridge engineering will at once be seen.

Amongst the most useful and least expensive bridges on the suspension principle, are those so frequently employed in mining districts, consisting of wire ropes, sometimes of great length, extending from a high level to a low level, such as from a mountain side to an adjacent river wharf, or to a seaside pier. Trucks containing minerals, etc., are suspended from these ropes, and made easily workable by means of grooved pulleys which run upon them, and thus enable the loaded wagons in their descent to haul up the empty ones. As the strain upon the ropes is equal to many times the load upon them, the greatest care is taken to make their end fixings secure. When this is properly done, passengers as well as goods may be carried with safety across chasms 1,000 feet deep, in any part of the globe.

At Monte Penna, in Spain, a continuous span system across mountain peaks is adopted over openings ranging from 85 feet to 2,230 feet, so fully recognised, however, is the value of this method of transport,

especially in inaccessible districts, that it is now extensively employed both at home and abroad.

The timber trestle railway bridges of America have been much used where timber is abundant, one of which, only recently opened, and 23 miles in length, crosses the great Salt Lake of Utah at a point twelve miles from land, and through water from 30 to 35 feet in depth.

These are but a few of the leading characteristics of bridges in different countries which require to be adapted to the ever changing conditions already referred to.

Personally speaking, no bridge has ever had centred around it so much of a fascinating nature as the Britannia, at the Menai Straits, owing to the fact that it was infinitely ahead of all other bridges of the period in size, in construction, in erection, in surrounding features, and, above all, in the elaborate series of experiments and calculations made by Mr. William Fairbairn at his works, assisted by Mr. Robert Stephenson, as engineer-in-chief of the Chester and Holyhead (now the London and North-Western Railway), which eventually showed them the strongest and most suitable form of main girders to adopt.

One of the latest great undertakings of this nature has been the construction of a new *lattice* bridge across the river St. Lawrence, at Montreal, for the Grand Trunk Railway Company, to take the place of the single line box girder bridge built by Mr. Stephenson

in 1860. The new bridge—of two miles in length—carries not only a double line of railway, but two electric tram lines, a carriage way, and a passenger roadway, and allows the beautiful surrounding scenery to be clearly viewed when crossing it. Moreover, the new structure was erected *around the old one* while the running of trains, until the last, was in full swing, thus obviating stoppage to traffic at any time.

To prevent any one from imagining that *Life as an Engineer*, in its higher flights of practice, is all glamour, and glory, and fame, and honour, and riches, and temporary immortality, let me here give a few notes from the career of Mr. Stephenson, one of the most distinguished and extremely busy of the early railway practitioners. Indeed, it may be said that many engineers, since his time, have had their seasons of grave anxiety, and even serious loss, through the sometimes unmanageable nature of the work they had to perform.

The difficulties attending the erection of the Britannia Bridge—which was opened in 1850—may be gathered from the fact that it consisted of four spans of gigantic rectangular rivetted tubes, the two largest of which were 460 feet each in span, and 1,587 tons each in weight. These, as well as the others, had to be lifted by means of hydraulic presses to a height of 125 feet above water level, which was eventually and most successfully accomplished. Mr. Stephenson had an extremely anxious and often sleepless time over this unique undertaking, and, upon the completion of the

last tube, replied to the congratulations of a large and deeply interested company as follows:—

> Not all the triumph which has attended this great work, and the solution of the difficult problem of carrying a rigid roadway across an arm of the sea at such a height, can repay me for the anxieties I have gone through, the friendships I have compromised, and the unworthy motives which have been attributed to me; and were another work of the same magnitude offered to me with like consequences, I would not for worlds undertake it.

The early engineers were a splendid race. The knowledge they acquired was through their own self-education and perseverance. They had everything to learn, not only technically, but in connection with the forces of nature, which were often arrayed against them. They sometimes made mistakes, which only taught them how to win success in the future, and even Mr. Stephenson was not exempt from temporary failures through causes beyond his control. In the erection of the Britannia Bridge he was, on one occasion, exposed to grave peril from what might have been an appalling disaster to the structure. This, however, was averted through the unceasing vigilance and forethought of the engineer-in-chief. And yet, when the mental strain was removed, Robert could look one of the happiest of mortals, just as if he thought that there had been no profession since the Creation which could in any way be compared with the one he himself so brilliantly adorned.

Works connected with the drainage, irrigation, and reclamation of land, also fall within the province of the civil engineer, and contribute in no small degree to the welfare of nations as well as that of private companies and individuals. The *reclamation of land* on a great scale gives considerable employment to the mechanical engineer, upon whom so much of the success of the scheme depends when pumping operations are necessary; and one of the most notable examples is to be found at the Ferrara Marshes, in Northern Italy, the area of which is nearly 200 square miles, the total quantity of water lifted to a height of 12 feet, by means of four pairs of centrifugal pumping engines, exceeding 2,000 tons per minute. This machinery was made by Messrs. John & Henry Gwynne, of London, and is amongst the most powerful of its kind in the world.

The reclamation of territory in England has been of a most extensive character, as vast expanses of valuable land were two or three centuries ago completely under water. This has especially been the case on the banks of the Thames, from Richmond to Gravesend, and also in the great Fen district, which was from sixty to seventy miles long, and from twenty to thirty miles broad, but now contains about 680,000 acres of rich pasture.

Works of this kind are among the greatest that energy and perseverance have ever achieved; indeed the kingdom of Holland may be said to owe its very

existence to the great dykes that protect it from inundation by the sea. Up to 1170, what is now the Zuyder Zee, was almost entirely dry land, but in that year an awful storm-flood burst into the interior, and swept away cities and towns with immense loss of life. In 1237 and 1250 other floods caused the water space thus formed to assume its present area of about 1,400 square miles. A gigantic scheme is, however, at present being matured by means of which the lost land will be recovered, but this I hope to describe later on.

Numerous examples of the immensely enhanced value of land by means of *irrigation* are to be found abroad, the most important undertaking of this nature having been recently completed on the Nile.

So prodigious, indeed, so overwhelming have the mechanical resources of modern times become, that no one need be surprised at anything which may happen. If the same progress is made during this century that was accomplished during the last, it is evident that there are wonders piled upon wonders for those who follow us, which the wildest flights of imagination are utterly unable to grasp, and which may produce effects upon the world infinitely beyond the conception of any one now living.

CHAPTER II.

MECHANICAL WONDERS OF THE WORKS—APPRENTICESHIP EXPERIENCES OF THE AUTHOR.

Shearing a Steel Locomotive Axle—Shearing a thick Steel Plate—Heavy Electrical Overhead transport — Powerful Machine treatment of a 100 ton Ingot—Silent bending of a colossal Armour Plate — Sawing of massive Steel Slabs — Modern Machinery in General Manufacturing processes—Its unlimited Scope—Wonderful Properties of the new Rapid Cutting Tool Steel — *Leaves from the Author's career* — Commencing as an Apprentice in Railway Engineering — The Works — Their various Departments — Fascinations of Whitworth's machinery—Apprenticeship with Messrs. Denny & Co., Dumbarton—Their great Prosperity—Strikes and their Effects—Practice in the Shops—My Contemporaries in the Works—Our Chief Draughtsman—The Firm of To-day—Its Steam Turbine Engine Enterprise.

As I have had the privilege of carefully inspecting many of the largest and newest engineering establishments, allow me, kind reader, to imaginarily indicate to you, at the outset, just a few of their most striking and picturesque performances which will be described in detail later on. In this there will be much of an astonishing nature, especially when it is considered that instead of iron, as formerly, the material now in almost universal use is tough steel, for which special preparations have had to be made.

What, for example, would you think if you saw a locomotive axle snipped through by a powerful machine with as much apparent ease as if the former had been a piece of whipcord, and the latter a pair of scissors; or a boiler plate, $1\frac{1}{2}''$ thick, similarly severed, or punched with large holes as if it had been so much cardboard—bearing in mind, at the same time, that plates of this thickness have been made up to 88 feet in length by 12 feet in breadth. Specially interesting would be the lifting of a 100 ton gun or casting by an overhead electric travelling crane, which silently, safely, and rapidly whisks it through the air, and lands it at some desired and distant part of an immense shop.

Another scene of great interest would be a gigantic and magnificent turning lathe, with a steel ingot of 60 to 100 tons suspended between its centres, and being reduced in diameter by means of tools which noiselessly and steadily take continuous cuts off it about $1\frac{1}{2}''$ in depth, to prepare it for the forging process.

In a great marine engineering establishment, the immense plates for the 300 pounds per square inch steam pressure boilers of a 20,000 ton ship may be seen in the act of being curved, from flat to an exact circle, as if they had been made of tin; and afterwards operated upon in another machine, which in *silence*—instead of deafening noise, as of yore—rivets them together.

In some other works still more remarkable performances than those just named may be viewed,

including the silent bending of a 30 or 40 ton armour plate to fit exactly the side of a £1,500,000 battle ship, now building hundreds of miles away. How this is accomplished will be explained later on. It may be well to state, moreover, that an armour plate has actually been rolled from a nickel steel ingot weighing 128 tons, the finished weight of the plate being 104 tons, its length 43 feet, its breadth 11 feet, and thickness 12 inches.

Before proceeding further, we may mention the extraordinary performances of the modern band saw, which at one time was only used for wood, but is now extensively employed in cutting variously shaped and massive engine details out of solid blocks of cold steel, to save the cost of the more expensive processes formerly in use. This sawing business reaches a climax in places such as Sir John Brown's, and Messrs. Cammell, Laird & Co., of Sheffield, etc. In these establishments one may see long armour plates ripped on both sides at once while in a cherry red hot state by two large circular saws which, with outrageous noise and firework showers of glowing metal, rapidly cut their way from end to end.

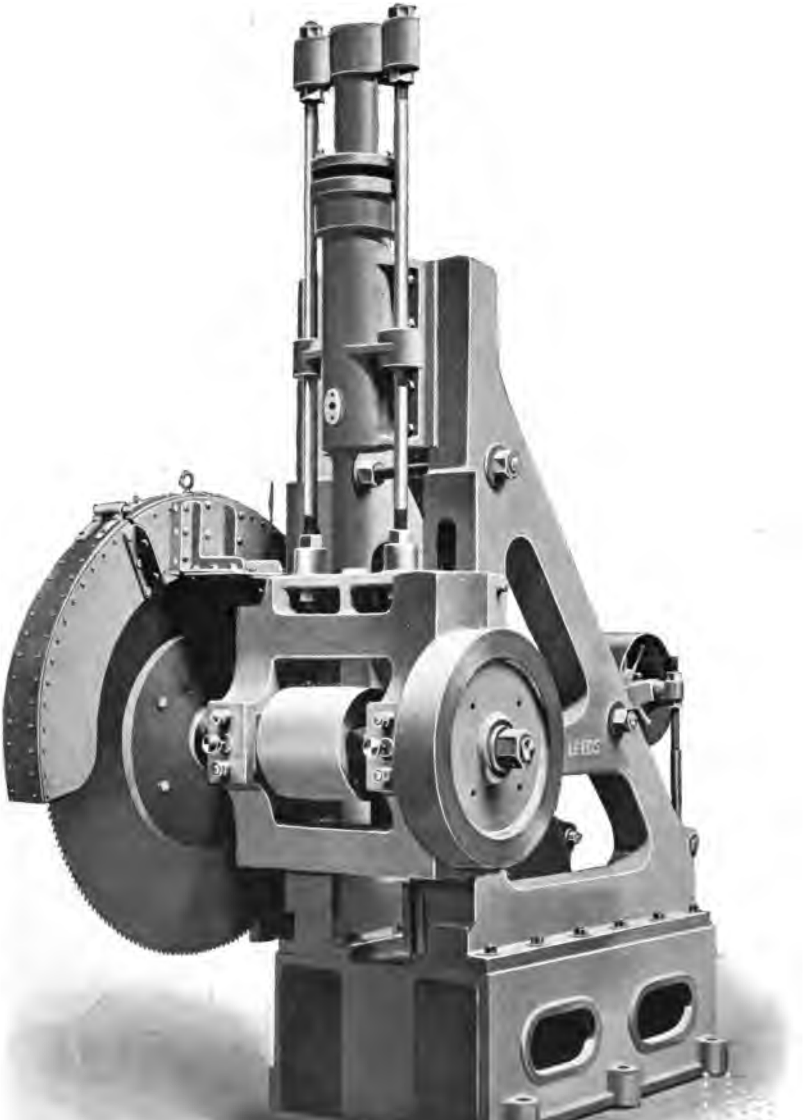
You might gaze in astonishment at this performance. You might say: "These saws must now be useless." By no means, they are ready to begin again on another plate, the reason being that they were made of a special kind of steel which is now used for rapid cutting tools of wonderful endurance, and which would have

astounded the famous sword-blade manufacturers of ancient Damascus.

An illustration of a somewhat novel electric driven *Hot Sawing Machine*, by Messrs. Henry Berry & Co., of Leeds, is shown in the next Plate, its accessories having been omitted to enable the working parts to be more easily seen. The electric motor is placed at the back, and as the driving belt is horizontal, the vertical sliding carriage which carries the saw is easily controlled. When required to cut bars as they come from the adjacent rolling mill, the saw carriage is raised by means of the overhead hydraulic cylinder, and, as the water is allowed to escape from this more or less rapidly, the descent of the saw by gravity enables the work to be performed with expedition.

The great value of this improved steel, from a workshop point of view, may be gathered from the fact that many exhaustive and official experiments were recently made to ascertain the best conditions under which it can be employed. These experiments are published in a very useful and admirably arranged book, price 2/6, which every engineer should study, its title being—*Dr. J. T. Nicholson's Report on Experiments with Rapid Cutting Steel Tools, made at the Manchester Municipal School of Technology.* From this, and also from other sources of information connected with various works, it is evident that the experiments just named are amongst the most valuable of the age.

So popular has this extraordinary metal become, that



ELECTRICALLY DRIVEN HOT SAWING MACHINE.

many machines have been re-designed to suit the severe conditions of service which their new tools impose upon them. One of these is the *Special Heavy Lathe* for high-speed cutting, shown in the next Plate, which can be belt-driven by a separate electric motor, or, if required, the motor can be fixed on the lathe itself. Various improvements have been introduced into this machine, the most conspicuous of which is the substitution of a broad parallel belt-driving pulley in place of the usual driving *cone*, the variations in speed being otherwise obtained.

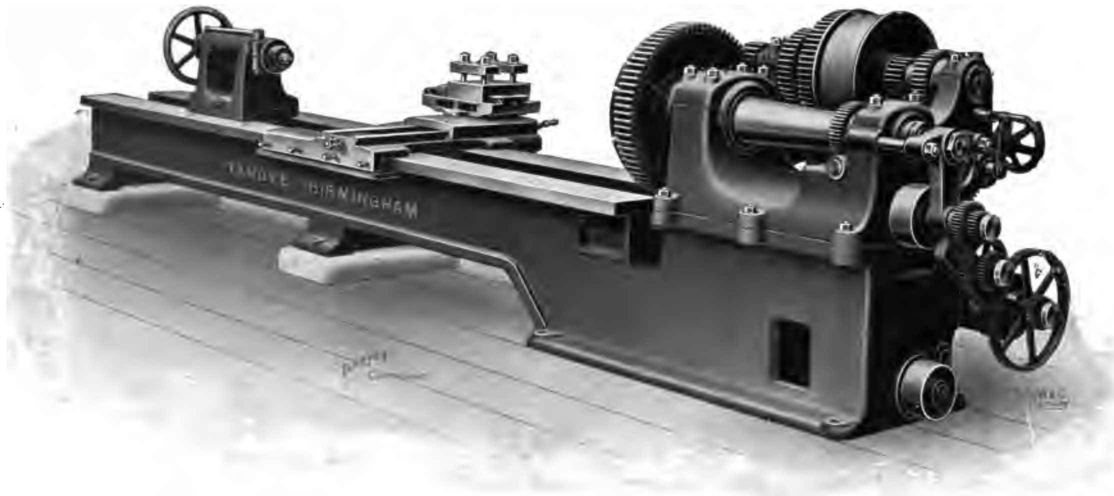
The artist has, by means of a back view, shown much that could not in any other way be visible, besides introducing an interesting novelty in lathe illustrations.

From these few remarks it will be seen that in engineering, even at its portals, we have a few mysteries quite as profound as some of those the conjurors possess, until you know "how the thing is done."

On this theme I might proceed to any length, but before passing on, it may be well to say that amongst the textile and infinitely varied works of all kinds of every day application, the most wonderful processes are to be seen—processes which, collectively, have so enormously decreased the cost of production and also of transport, that there is really nothing we can eat, drink, wear or use, in any possible form, that does not owe its cheapness and excellence and abundance to the skill of the engineer.

Having very briefly tried to indicate the nature of engineering as it is to-day, it will be advisable to show how a knowledge of it may be best obtained. To do this effectively, it may be well to graphically outline my own career, and explain the various systems now adopted to obtain the desired information. Incidentally, too, I shall describe the work in its various phases, and also give a few passing glimpses of the life careers of those who have adorned this delightful path of science.

When I thought about commencing business, it was intended that I should enter an Edinburgh bank, but as it proved there would not be a vacancy for two years, I had to look out for something else. Strangely enough, I had a great love of engineering drawing, which induced two of my friends to propose that I should learn practical engineering, and efforts were therefore made in that direction. This, however, I did not much like, as a young friend of mine was at that time an apprentice in Hawthorn's locomotive establishment, in Leith, and had to get up at five in the morning to enable him to be at the works by six. He used to tell us about the strictness in the works, what they did if he came late, and what they didn't do if he did something else, and how they were fined for making tools for themselves. All this set me more against it, but it was of no avail, as I had lost my father in Australia when very young, had only my own efforts to trust to, and had therefore to make a start in the works of the



SPECIAL HEAVY LATHE FOR HIGH SPEED CUTTING.

North British Railway Company. No sooner, however, did I see Whitworth's machinery, with which the establishment abounded, than I became fascinated with it, and from that day to this have never ceased to take a deep interest in everything relating to the profession.

Whitworth's machines were, even then, remarkable for extreme elegance and simplicity of design, their fitting together was absolutely faultless, and their finish could not be surpassed. I saw other firm's productions as well, but although they did good work, they were very commonplace in appearance.

These works contained the usual array of Drawing office, General office, Pattern shop, Machine shops, Fitting and Erecting shops, Brass and Iron foundries, Forge and Smithy, Spring shop, Engine running shed, Carriage shed, Carriage and Wagon shops, etc., and gave me, at the outset, a very fair idea of railway practice, as they controlled the work of the whole line in all its details. The winters of the period were very long and very cold, and the shops in every way very inferior to those of the present. Whitworth's machines had, however, so fired me with enthusiasm, that I immediately began to study their various properties in detail, and also in combined form. The main driving and other engines and machinery, the locomotives themselves, and everything else came under close observation, and thus I had my time well and happily occupied from the outset.

After fully two years of railway practice, the

influence of another kind friend enabled me to be admitted as a half-time apprentice to the works of Messrs. Tulloch & Denny, now Denny & Co., Dumbarton, where I came in for a great variety of delightful practice in marine engineering. And all the more so, as machines not being nearly so much used as they are now, we had to perform the most beautifully fitted and finished work by means of hand tools, of which the hammer, chisel, and file were the principal. As these required considerable skill in their use, we took great pleasure in trying to become first-rate hands, and eventually succeeded.

Dumbarton at this time was a very quiet place, provided you kept out of hearing range of the clattering of the hammers in the various shipyards. The Engine Works were washed on two sides by the Leven—a broad outlet of Loch Lomond—and were also fully open to the Vale of Leven and the grand mountain scenery of Dumbartonshire. In short, there could hardly have been a work more pleasantly situated.

Such, then, was the place where I had to reside for at least three years, broken at intervals by a few days' holiday in July and December, and by occasional brief visits to Glasgow.

In former times, Caird, of Greenock, had made all the engines that were required for the ships built by the Dennys, but in 1851, the establishment I had just entered was opened to meet a want which had been increasingly felt, and with the result that for a long

time afterwards they were inundated with orders. Indeed, for two years from the time I began, eight and ten o'clock was the order of the day—or night—for most of the hands.

Amongst numerous vessels we had in progress were the two large and now historic screw steamers *Alps* and *Andes*, with which the Cunard Company opened out their path on the Mediterranean station. Their engines were of the now long-extinct beam-spur-wheel-geared 25 pound steam description, but which, like those of the equally extinct side-lever order, had special virtues of their own.

The men and boys in the engineering works were remarkably steady and well-conducted, and during the whole period I was among them, often worked much more than six days a week on account of "overtime," of which many became tired however, although "time and quarter" from six to eight, and "time and half" from eight to ten o'clock, were considerable advantages in a pecuniary way. The ship builders, on the other hand, were an unmanageable crew. At one time the rivetters would strike, and the "holder up" boys go off for a holiday. Then the youths would strike, and their masters—the rivetters—"go on the spree."

Next in order came the platers, who thought they might try their fortune; the carpenters and joiners following in the rear. Thus they went on by stages until some one found out that "union was strength"—then they *all* struck. On one occasion Mr. William

Denny had received an order for four good sized steamers, which were to be built with all speed. No sooner did this become known than the men struck at once for more pay, but as the work was not quite begun, Mr. Denny immediately handed over the whole contract to Caird.

I have mentioned these facts because they reflect light upon similar events of the present time on a stupendous scale at home and abroad. Events, too, which have caused enormous losses both to men and to masters, not only by delay in the execution of a contract, but, by unduly enhanced prices, driving work from the country which should be done here. After, however, the disastrous experiences of the past, it is to be hoped that a better era is at hand. The professional cares and worries of responsible engineers are often so exacting that they may well be spared from such sources of annoyance and loss as those just named, which, in most cases, might easily be settled by arbitration.

I had not been long in the works before I discovered that it would be a source of great pleasure and advantage if I could get permission, during leisure hours, to sketch and take dimensions of the various details of the engines in progress, and draw them out fully to scale at home—plans, sections and elevations, and in built up form as complete general drawings. This privilege I succeeded in obtaining, and during the whole of my apprenticeship esteemed it all the more highly

because engineers at that time were very jealous of anyone in their employment taking notes, and as "leisure time" proved to be part of the dinner hour, as well as Saturday afternoons and summer evenings when necessary, I had always plenty to do. It was splendid and fascinating practice, but it often gave me more work than I cared for, and very frequently allowed me only four-and-a-half hours' sleep, when the drawings had to be sufficiently far advanced before the engines were taken to pieces in the erecting shop.

One of the memorable events that happened in my last year was an awful storm. We were on that occasion working till midnight, erecting the engines of the *Min*, a China steamer, and, as one of those so employed, I went home for tea at six. A calm prevailed, but soon afterwards the wind began to rise in gusts, until about eleven o'clock, when we were in the middle of a perfect West Indian tornado, and as the works were fully exposed, we felt the tempest in all its fury. Things seemed as if they were going to pieces, and had the great doors of the building not been securely stayed inside with timber props, they would have been blown in, and great damage might have resulted.

Since that eventful night, I have witnessed many a terrible storm, but never one so destructive to property, nor one which left its marks behind it for such a length of time. Helensburgh stone pier was destroyed, and many house windows blown in, tall chimneys, etc.,

thrown down, and amongst a variety of other disasters, was the wreck of Tod & McGregor's building shed, which had recently been erected in Crystal Palace style, at a cost of £15,000.

A correct knowledge of the force of wind is most essential to an engineer, but strange to say, until after the Tay Bridge came down, the greatest authorities on the subject differed very widely. Some said one thing, and some another, but no one seemed to know what the greatest wind stresses really were.

During a recent excursion to the country, however, I came to know something about those atmospheric disturbances which sometimes appear mysterious.

While our party were visiting the residence of Mr. Worsley, near Winwick, Lancashire, he showed us a part of his grounds which had been injured by a storm some years before. Upon questioning him about it, he told me that, when at its height, a blast of most intense and concentrated energy had swept over his garden, cutting like a knife through some rhododendron bushes, and snapping off two trees near the root, besides doing other damage. The strange part of it was, that outside of this contracted area no mischief was done. In the tropics, however, such experiences are by no means uncommon.

Another event that happened at Dumbarton in those days, was the death of Mr. William Denny—*the* Denny. He was of short stature, and had a very mild, gentle, unassuming manner. He also was the genius of

the family, and had conducted most successfully the very celebrated establishment over which his father and grandfather had reigned before him since the year 1814.

The day of the funeral was a day of silence, as the various works were closed, and we all escorted his remains to their resting place. Thus passed away from among us, at an early age, one to whom Dumbarton owed much of her prosperity.

We had very good foremen amongst the Engineers—one of whom, Mr. Rankin, became the head of works of his own in Greenock, the name of the firm being Rankin & Blackmore. Another of our foremen was William Campbell, a fresh-coloured, light-haired man. A great word of his was "tosh"—to finish—"tosh" this, and "tosh" that. On one occasion he said to me "I wish you would tosh that hand pump gear a little better, and keep the people from glowring at it." This pump was to go on the deck of the new paddle steamer *Yorkshireman*, which was nearly completed, and as it was to be exposed to the weather, I thought high art quite unnecessary—a tale, however, hangs by that ship.

She was constructed under a penalty of £100 a week for delay, and Mr. Archibald Denny, who built her, lost £900 through this transaction: but on her first voyage, she was wrecked in the Belfast Lough, where she lay broken in two. Mr. Denny now bought the hull, raised it, and had it towed to his yard, and lengthened. Her fine side lever engines were brought to our department

in a terrible condition through rust. We, however, cleaned, polished, re-erected, and painted them, till they looked as good as new. The vessel was treated in the same manner, and when completed was sold under the name of *Waterloo*, bringing her builder a net profit of £10,000.

Mr. Campbell afterwards became a steamship superintending-engineer at Fleetwood, to his own satisfaction and that of his Company.

Mr. William Wallace was our accomplished chief draughtsman. When, however, we built the first steamers, *Canadian*, *Indian*, *Anglo-Saxon*, and *North American*, for the Allan Line in Liverpool, he became their superintending engineer, from which post he has not long retired.

Retrospectively glancing through the vista of many years, I cannot but feel thankful that steel—that abomination for the hand tool workers of to-day—was almost unknown at that time. Had it been otherwise, I do not know how we could have made pleasant progress with such refractory metals to operate upon as are now constantly employed in general engineering. Wrought iron was much about the same as it is at present, but cast iron has been so much improved in strength by scientific treatment, as sometimes to resist almost everything but machine tools, which are consequently more useful than ever. The judicious employment of the metals named has thus been the means of greatly reducing the weight of machinery, and this in itself is

an important advantage for shipowners and others, especially when the cost of constructing it has been much diminished by means of recent inventions, for which engineers are alone responsible.

Since the time referred to in this chapter, the engineering, and also the shipbuilding establishments of the Messrs. Denny have been immensely improved, enlarged, and, indeed, remodelled. Their system of management is one of the best that could have been devised, and one, too, which greatly pleases their employés of all ranks on account of the benefits it confers upon them. I am very glad to think that the present firm was enterprising enough to be the first to introduce into the merchant service Messrs. Parson's Steam Turbine engines on board the steamers *King Edward* and *Queen Alexandra*, the latter of which is shown in the frontispiece with its river Clyde surroundings.

So successful have these vessels proved, that orders for similarly-engined ships have followed to such an extent that Messrs. Denny & Co. have been compelled to lay down special machinery for the turbine engine manufacture on a large scale. This has been additionally rendered advisable by the decision of the Cunard Company to employ this type of propelling power in their new colossal ocean racers, as well as in others, a decision which will have a revolutionary effect upon the steam navigation of the future, and which will be described later on.

CHAPTER III.

EARLY EXPERIENCES CONTINUED.

Drawing Office of Messrs. Neilson & Co., Locomotive and General Engineers, Glasgow—The Firm, Past and Present—*A secret Cause of Fires discovered*—Drawing Office of Messrs. Tod & Macgregor, Glasgow—How they bossed the early P. & O. and Inman Company's Fleets—New Era-making R.M.S. *Bengal*—The "Happy Man" of the Firm—Immense Passenger Traffic created by the Clyde River Steamers—Hints for the Thames—Building of the Cunard R.M.S. *Persia* by Napier—The Sensation of the Period—Robert Napier's self-taught career—His first orders for the Cunard Co.—Magnificent Success—Immense future orders from the Cunard Co. and British and Foreign Governments, etc.—The Clyde a centre of wonderful Engineering progress—Early Designers of the Marine Engine—Their Difficulties.

I LEFT Dumbarton in 1857 to enter, as a draughtsman, the celebrated Hyde Park Foundry of Messrs. Neilson & Co., Glasgow, who were at that time considered the best "General" engineering people in that city, and made marine, locomotive, pumping, blowing, etc., engines, and a variety of other work. They had such a large and rapidly extending business that the firm were, in 1860, compelled to remove to Springburn, in the suburbs, where they built, upon the latest and best lines, the largest establishment of its kind in Europe for locomotive work alone.

Aided by the most labour-saving machinery, it is only natural that the Hyde Park Locomotive Works should be noted for their rapid execution of contracts, a recent one of which was with the Nippon Railway of Japan for twelve tank engines, involving complete sets of drawings and patterns. These engines had to be delivered within 139 days, under a penalty of £100 per engine per week; they were all, however, passed under steam within 84 days from the receipt of the order.

This establishment bristles with an immense quantity of most interesting machinery, including various kinds of electric, hydraulic, and pneumatic engines and tools, but, as much will be said on these points in other chapters, I need here only refer to the *Drawing Office* and the *Principals*. The former is 105 feet long by 35 feet broad, and has accommodation for 45 draughtsmen.

In addition to this main office there is a smaller one, which is occupied by twelve machine draughtsmen, and also a special room, 70 feet by 18 feet, containing twenty young lady tracers who are constantly employed. Further, there is a photographic printing room for duplicating the tracings made by these ladies, and besides other rooms connected with the main Drawing Office, there is one for the laying out of plans for the use of engineers who visit the works to inspect the engines in progress, and also another handsome apartment for the reception of visitors.

During the time I was on the staff of the Hyde Park

Works, Mr. Walter Montgomerie Neilson was their head and front, a keenly intellectual-looking man, whose best energies were devoted to the multifarious occupations which a very busy life entailed upon him. His father, Mr. Beaumont Neilson, had some time before invented the Hot Blast system of melting iron ore in blast furnaces, which completely revolutionised the process, and greatly reduced the cost of production.

Our Mr. Neilson was a restless being. He was always thinking, cogitating, plodding, plotting, planning, scheming, and sketching out some idea which he hoped to perfect in a practical form. If he did not succeed at first, he tried again and again, until he did so, hence the fame of the establishment over which he so admirably presided—in other words, he let genius, sudden inspiration, flashes of thought, and brilliant scintillations of the mind give him his initial ideas, but trusted the rest to his own industry, perseverance, and irresistible enthusiasm, which, we may add, have often been the secret of success with others.

His manager, at that period, was Mr. James Reid, who had been trained to marine engineering in the famous works of Messrs. Scott & Sinclair, and also Messrs. Caird & Co., of Greenock. Although locomotive and general engineering were quite new themes for him, he soon mastered them, and not only ably conducted his own special branch, but the others as well. This fact, with many other later ones of similar nature, confirms me in the belief that good *marine* hands

can undertake any kind of work into which they can put their hearts and minds.

In course of time Mr. Reid was invited to become the manager of the renowned Atlas works of Messrs. Sharp, Stewart & Co., of Manchester, where he remained for some years, until, eventually, Mr. Neilson requested him to return to the new "Hyde Park" as managing partner. Upon the death of Mr. Neilson, he became the sole proprietor until his own decease, when the works passed into the hands of his sons, of whom Mr. Hugh Reid was the senior partner, the firm then being known as Neilson, Reid & Co.

After Mr. James Reid left us, Mr. Dübs became our managing partner until 1863, when he started a large and prosperous locomotive establishment for himself in Glasgow. Later on, Messrs. Sharp, Stewart & Co. removed from Manchester to their splendidly appointed new Atlas works at Springburn, where they well-sustained their southern fame. Now, however, the three establishments referred to have become amalgamated under the title of the "North British Locomotive Company Limited."

An event happened during my time in the Old Works which may throw light upon some of the mysterious fires of modern days. The foreman—Mr. Webster—of the first-floor machine shop, had left as usual at six o'clock one evening, and, upon his arrival next morning at 5.45, found a large heap of dirty, oily cotton waste, which lay on the floor, just on the point of bursting into

flame. Had it done so, the total destruction of the establishment would have followed, and no one, to this day, would have known how it came about. It did not then seem to be known that waste, as described, or rags, are liable to spontaneous combustion through chemical action, so much so, indeed, that we may reasonably attribute many of the most mysterious conflagrations to this cause alone. Even private houses are not exempt from this peril, as I have since learnt.

After having been about three years in the office of Messrs. Neilson & Co., I obtained a more lucrative appointment in the famous works of Messrs. Tod & Macgregor, marine engineers and shipbuilders, Clyde Foundry, of the same city. For many years this firm had constructed vessels for the Peninsular and Oriental Company, whose last paddle steamers, the *Ganges* and *Singapore*, were built in 1852. At that time the screw-propeller was becoming better known, the above Company therefore gave it a trial, by requesting Mr. Tod to build for them the s.s. *Bengal*, and so highly pleased were they with the performances of this ship that paddles were discarded ever after.

Amongst the numerous P. and O. ships that followed, was the *Delhi*, which had vertical trunk engines, but, owing to the Indian mutiny atrocities at this period, they changed her name to the *Nemesis*, or the *Avenger*.

The Inman and other Companies also gave them many vessels to build, having in nearly every case Mr.

Tod's steeple engines. Their machinery was elegantly designed: light, strong, and highly-finished in all the parts. The engine-room had also abundance of natural light, and every detail was easily accessible and easily seen; whilst those on the starting platform, or on the upper deck, could take in at a glance everything around them or below them. With many other firms, too, these engines were very popular, for paddle as well as for screw steamers of all sizes. Messrs. Tod & Macgregor were also greatly in favour with the Egyptians, and especially with the Pasha, for whom they built several beautiful steamers having oscillating engines, one of which—the *Faid Rabani*, or *Light of Heaven*—was fitted up as a steam yacht in magnificent style, at a cost of £70,000.

Mr. Tod died in 1859, and Mr. Macgregor, of the shipyard at Partick, six weeks afterwards. Mr. William Tod, the eldest son, now assumed the management of the engineering department, and I entered his drawing-office in 1861. This gentleman was most genial and kind-hearted, and I shall ever remember with much pleasure the generous manner in which he prevented me from accepting an invitation from Mr. John Elder to join his well-known works.

Another Clyde Foundry worthy was Mr. R. F. Pearce, the business manager, formerly of Chester. There are people we sometimes meet who have an unhappy talent for looking on the dismal side of everything, either in expectation or in possession, and for

colouring their surroundings with Payne's grey or neutral tint, not to mention Indian ink or lamp black. If the sun shines, or the flowers bloom, or the health-giving breezes blow, they think they are for others, but not for them, and all because these unfortunates are unable to extract the sting from the nettle,—the bitter from the sweet in life,—and either do not know, or seem to forget, that the world in general is pretty much what we make it for ourselves.

There are others, however, who, in the midst of anxiety, and perhaps trouble, are bright and happy, though often cast down, and still more happy when the end draws near, because they are masters of the art of painting their thoughts and actions with liquid sunshine drawn from the heavens, and helping to tint those around them in a similar manner. To a large extent Mr. Pearce was one of the latter. He was essentially a "Happy Man"—one who never seemed to feel he was getting older, or that there was any care and anxiety in *his* part of the world at least. He enjoyed his own jokes immensely, and liked sometimes to come into our office to tell some interesting story, and ask kindly about all of us. With me the memory of those two good friends will be ever green.

For twelve miles below Glasgow the Clyde is almost as artificial as the Suez Canal, and during the early part of the last century was only navigable to the Broomielaw during spring tides, by vessels drawing about eight feet of water. The only communication

between the city and places down the river in those days was by boats, and a story of the period is, that one dark night a party went on board one of them for a row to Greenock. They started, and in the early morning one of the oarsmen cried out, "Hey, Jock, here's Dumbarton Castle!" "Where?" said his friend at the other oar. "There," said he, pointing to what on closer inspection proved to be the Broomielaw after all. They had toiled all night, quite forgetting that the boat was moored by the stern!

The river steamers have always been celebrated for their speed and beauty, and have caused as much rivalry among their builders and engineers as if they had been ocean liners. At the present time some of them are truly magnificent, and may be said to have no equals in Europe. Especially is this the case with the *Columba* and *Lord of the Isles*. The former goes to Ardishaig and back the same day, or a distance of 180 miles in about eleven hours, including numerous stoppages; and the latter to Inverary and back, or 218 miles in thirteen hours.

The *Columba* carries the mails, and is 316 feet long, by 50 feet broad over the paddle boxes, her draft being nearly 6 feet. The deck saloon, which runs about three-fourths of her length, and full breadth of ship, is magnificently fitted up, and below this is the dining saloon, where 140 can sit at table with as much comfort and style as in a first-class hotel. At the post office, letters and telegrams are received and money orders

paid. There is also a hair dressing establishment, a bathroom, a bookstall, a fruit stall, a cloakroom, and tables for writing letters, at which ladies and gentlemen are constantly engaged during the season. Besides a handsome piano at the end of the saloon, there is generally a good instrumental band on deck, which greatly adds to the enjoyment of a trip which only costs six shillings for the whole day. The vessel, externally and internally, has the finish and appearance of a modern Cunarder, and is propelled by a pair of splendid oscillating engines at a speed of 22 miles an hour.

The *Lord of the Isles*, on her run to Inverary, can do 23 miles in the same time. The following story is told about the Kyles of Bute, through which these steamers pass every day :—

When the late Mr. Charles MacIver went to live at Rothesay, he engaged John Taylor, an old man-o'-war's man, as pilot for his steam yacht. The first time Mr. MacIver sailed through the dangerous "narrows," he said to his Ancient Mariner :

"Now, are you sure you know this place well ?"

"Know it ?" said John, "I ken every rock on this coast, from Cape Wrath to the Mull o' Galloway—there's *one o' them*," he added, as the ship bumped against a sunken reef.

I may here add that, in view of the grand successes of the Clyde steamers for he last fifty years, and the immense passenger traffic they have created, it is

surprising that the Thames should not long ago have had a similarly attractive and profitable service.

All the early Cunard steamers, from the *Britannia* onwards, were built of timber, the largest of which were of 2,250 tons, 300 feet in length, and 42 feet in breadth. The steam cylinders of their side-lever engines were 90 inches in diameter, with an eight-feet stroke of piston, the diameter of the paddle wheels being 36 feet. In 1855, however, the *iron* paddle-steamer *Persia* was launched from Napier's.

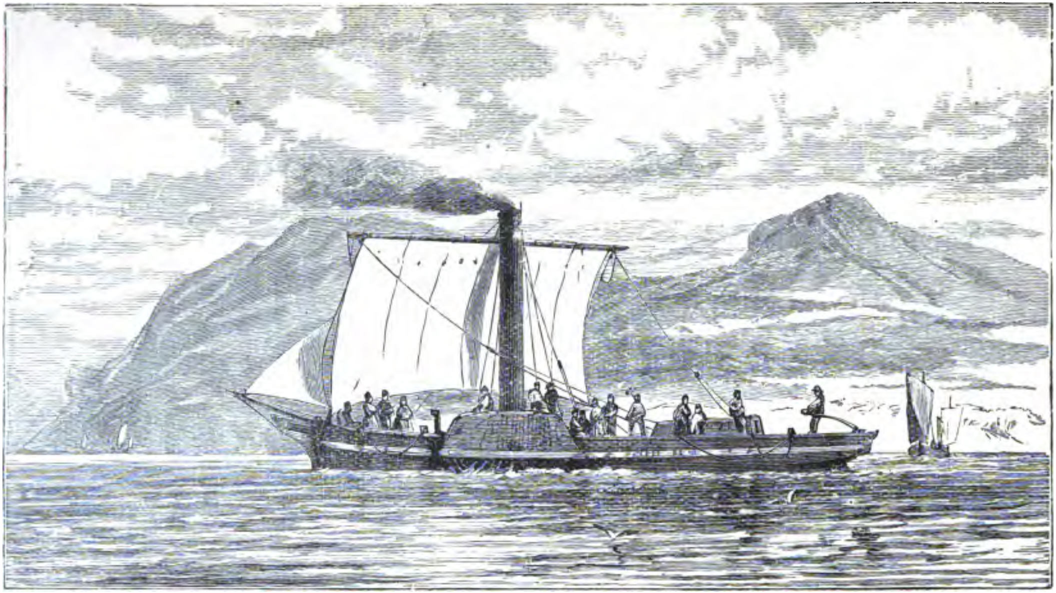
What a sensation this ship caused on the Clyde while building! The largest vessel hitherto launched on that river was Tod & Macgregor's P. and O. steamer *Simla*, of 2,600 tons, a large working model of whose magnificent engines adorned the Crystal Palace for many years; but here was a paddle ship of the unheard of size of 3,500 tons actually in course of construction. Many a discussion we had about her in Denny's—indeed, before the order was settled, the general hope was that our firm might have the building of the vessel, since we had a reputation good enough for anything. As our cranes, however, were hardly strong enough for such colossal engines, we were content to let Napier get the contract.

The *Persia's* length over all was 390 feet, breadth over paddle boxes, 71 feet, and depth, 32 feet. Her hull was immensely strong, and every care was taken to make her the best, safest, and quickest ship at that time afloat.

In 1862, the iron paddle steamer *Scotia* was built by the same firm for the Cunard Company. She was of still larger dimensions than the *Persia*, but as it soon became fully apparent that the screw was the best means of propulsion for ocean navigaticn, paddles were henceforth abolished.

At this period none of the great Engineering people in the Clyde district attained such high celebrity as Robert Napier. This was attributable to two main causes,—one being the antiquity of his establishment, and the other the excellence of the work he turned out, in design, material, and also workmanship, which could not be surpassed.

Like many of the great engineers who have left their footprints on the sands of time, Mr. Napier was a self-taught genius, being in his youth only a Dumbarton blacksmith. The success of the *Comet*—a view of which is shown on the next page—however, in 1812, so fired him with enthusiasm, that soon afterwards he started a small shop in Glasgow, which formed the nucleus of the famous Vulcan Foundry, and, later on, the still larger and more renowned Lancefield Works. The shipbuilding yard followed in course of time, and from it the R. M. S. *Persia*, *Scotia*, H. M. S. *Black Prince*, and many other magnificent vessels were subsequently launched. With the early coasting steamers Mr. Napier had much to do, but the event of all others for importance, was the visit paid to him in 1839 by Mr. Cunard, Mr. Burns, and Mr. MacIver, with the



"COMET" ON THE CLYDE, 1812.

object of forming a Company, entitled "The British and North American Royal Mail Steam Packet Company," which was afterwards altered to the simple "Cunard Company" for obvious reasons.

From the time Mr. Napier began the engines of their first ship, *Britannia*, in the above year, his professional advancement was astonishing, as the Cunard Company gave him all their subsequent Atlantic ships to engine. The Government supplied him with plenty of work, including as many as twenty-four sets of gunboat engines in one order. He was also favoured by Foreign Governments, and by many leading steamship companies at home and abroad.

I well remember the building of H. M. S. *Black Prince*. She was the largest and most magnificent naval ship of her time, exquisitely beautiful in hull, and stately in masts and spars. As she was the longest and heaviest vessel that had been built on the Clyde, extraordinary precautions were taken to launch her in such a way as to keep her from touching the opposite bank of the river, which was accomplished by means of several cables which gradually brought her to rest after entering the water.

The day of the launch was a semi-holiday, and very wet. The tide reached its highest. The order to "Let go" was shouted out as usual on such occasions, and in a few moments down came the ship in most impressive style, with her stern sunk deep in the river, and raising such a wave before it, that many of the

thousands who lined our bank were nearly swept off their feet by the unexpected flood. The shipyard manager, who could not sleep for weeks over this most difficult undertaking, had his mind relieved at last when he saw his plans work out to perfection.

I hardly ever see, now-a-days, owing to compulsory economy at every point, such exquisitely finished work as we of this period turned out, as not only was every joint made practically invisible by hand labour, but in the polished parts not even a scratch was allowed to remain. Hence the extreme beauty of machinery in general in those days, when elegantly and suitably designed.

The foregoing remarks will, to some extent, indicate that Glasgow and the Clyde district have been—ever since the advent of the *Comet*—a centre of engineering advancement, intensified, however, in later years by the rise and progress of many new and subsequently well-known establishments for the construction of marine, locomotive, and general machinery of every description on a very extended scale. The wonder is that the early designers of the marine engine were enabled so to develop its proportions, without the aid of theoretical and experimental science, as to produce machinery which seldom became deranged at sea. And all the more so as, unlike the land engine, it was frequently exposed to the most severe, irregular, and sudden strains in rough weather. The side lever engine of the period, however, was slow and stately in its

motion, and of massive cast iron build for the sake of handsome architectural appearance, weight in a ship being evidently a secondary consideration.

Mr. Napier, however, swept away these ponderous details by introducing his light, elegant, and highly-finished *wrought iron* system of construction, the result being immunity from fracture, great reduction in weight of machinery, much greater accessibility to every working part, and immensely improved light in the engine room. These splendid innovations were copied by other engineers, who retained them in their own works, not only for this class of engine as long as it lasted, but for others as well.

Knowing from many sources the great difficulties that beset the practical designing of the early marine engine, through want of experimental data concerning the strength of materials, it is wonderful that we had not more breakdowns and minor accidents owing to want of strength at vital points, or through hidden flaws in castings and forgings, such as main-shafts, cross-heads, cross-tails, side levers, &c.

So far as land engineering is concerned, Sir William Fairbairn and Dr. Hodgkinson, of Manchester, unitedly and most extensively experimented upon cast and wrought iron beams, girders, columns, &c., in such a manner as to have supplied invaluable practical and theoretical information to the world of science ever since. During, however, a portion of Mr. David Kirk-aldy's long connection with the Lancefield Works,

Mr. Napier employed him in making most elaborate tests upon iron and steel plates, bars, &c., of different qualities, and under various conditions of strain, the profusely tabulated and described results of which were originally published in the year 1863, in a book entitled *Experiments on Wrought Iron and Steel.* With these facts, and multitudes of others since those days to guide them, engineers have had a solid basis for their calculations, which have enabled structures of all kinds to be so proportioned as to combine the greatest strength with the least expenditure of material and labour. Thus will be seen, in nut-shell form, a few only of the incidents connected with life as an engineer in the past, which have helped to make the world what it is to-day.

I spent some of my best and happiest years amongst the people referred to in the Clyde region, and have specially to remember it in connection with the year 1885, when on a holiday visit after long absence. While sailing in one of its splendid river steamers, on a lovely day, and in the midst of beautiful surroundings, I had a flash thought, as it were from the skies, which, in matured and developed form, was subsequently the means of saving me from unexpected disaster through causes beyond my control, and from which I am still benefitting.

CHAPTER IV.

LIFE ON THE STAFF OF MESSRS. LAIRD BROS., BIRKENHEAD.

An extremely busy period—Difference between Marine and Locomotive Establishments — Description of the Works — The Firm — Their Generous Treatment — The Staff — English, Scotch, Irish, Brazilian and American Pupils in the Drawing Office—Their various Idiosyncrasies—Their Success in After Life—How Don José became a Government Official of High Degree — How Don Eugénio obtained an honourable Post—Señor Antonio's versatile Accomplishments — From Life to unexpected Death for poor Billy — How ambitious Fred. injured his Constit*oo*tion by over Study—How studious Charley reached The Top—Useful Hints for Students—Chief Engineer of H.M.S. *Captain* — His irrepressible enthusiasm — Lairds' Foremen—Foremen in Small Works—The Workmen —Happy Remembrances of old Associates.

IN the year 1864, I had the pleasure of being engaged on the designing staff of Messrs. Laird Brothers, Birkenhead Iron Works, which were fully occupied with British and Foreign Government contracts, including H.M.S. *Agincourt*, etc., and several mercantile steamers. The number of men amounted to about 4,000, which, later on, was extensively increased. Considerable occupation was also given to others in the foundries which supplied the firm with brass and iron castings and copper work, and also in the great

forges where the heavy wrought-iron parts were made, such as main shafts, etc.

In this respect there is considerable difference between marine and locomotive works, the former giving out all their heavy forgings, and in many cases all their castings, to other people, as it is more economical to do so owing to the extreme variations in size that exist in steamship engines. The railway engineers, on the other hand, have no such variations, as locomotives do not alter much in dimensions, hence they make all their own forgings, castings, and copper work, and are thus completely self-contained in their operations. Everything, however, in the way of plating, as in boilers, tender water tanks, side frames, etc., are given to the rolling mills.

Besides the 4,000 men just mentioned, the Birkenhead Iron Works had a large staff of able foremen and experienced draughtsmen, both in the engineering and shipbuilding departments, and also a full complement of clerks in the general office. Two of the foremen had been in the works for about forty-five years as men and boys, and some of the others also for very extensive periods. The establishment comprised a *Pattern Shop*; one light, and two heavy *Machine Shops*; two *Erecting Shops*, in the last of which the most powerful engines could have been fitted up; a very spacious and admirably arranged new *Boiler Shop* outside the works; and an extensive *Smithy*, containing several steam hammers, and all other appliances for executing ship and engine

work generally. At this end of the premises were placed a large *Joinery* and *Cabinet-making Shop;* also a *Saw Mill,* with complete assortment of machines for sawing, planing, mortising, etc.

Over the smithy was a spacious *Mould Loft,* where the sections and plans of the vessels were drawn full-size on a black floor, so that the greatest accuracy might be ensured in their construction; and, adjoining this, was a supplementary *Drawing Office.* In the same locality were to be found the *Rigging Loft, Storerooms,* and buildings containing plate bending, punching and shearing, planing, drilling, and other ship constructing machinery.

At the other end of the works stood an extensive building containing all the *Principal Offices,* keeper's rooms, and a model room, which contained a large collection of very handsome models and oil paintings of ships built by the firm. Next to this, were the *Armour-plate Shops,* which contained heavy shafting lathes, planing, drilling, screwing, and other machines; also a powerful hydraulic press for bending the plates cold.

Lastly, we may add a large shed full of shipbuilding appliances, where all the frames or ribs of the vessels were bent to shape while red hot on a large iron face-plate. The erecting shops were swept longitudinally and transversely by very powerful overhead travelling cranes, and the larger of the two had, on one side, a few valuable machines, including one of gigantic size for combined planing and slotting work of the heaviest

character, also a lathe, whose face-plate was 15 feet in diameter. As the foundations of these buildings had been excavated out of solid rock, the floors were beautifully clean compared with others.

Owing to the amount of medium and small sized gear in all engines being very considerable, light machines and appliances of every description for rapidly executing first-class work were extensively employed.

There were five *Graving Docks*, two of which were covered, and under their roofs H. M. S. *Agincourt*, *Euphrates*, *Captain*, *Vanguard*, and many other large vessels were built, while another was used as a *Fitting-up Basin* for ships getting in their machinery and masts, and general fittings. There were also six *Building Slips*, which, in conjunction with the graving docks, had, during my time, full employment.

The heads of the firm were very good in giving the shipbuilders as well as ourselves most spacious and handsome offices, and, indeed, everything that tended to make us comfortable. Sometimes we all received invitations to a grand dinner, which was given in the large general office, and went off more or less enthusiastically according to circumstances.

The Engineering Manager—Mr. Restel Ratsey Bevis—was kind to all, and had a quiet, pleasant way of speaking to people—even when annoyed—that did him great credit. And if anything were wrongly made—which rarely happened—through an error in a drawing, he would point it out to the draughtsman, and

mildly say: "I am surprised that one of *your* experience could have done such a thing, don't let it occur again." The amount of time spent on plans he supervised was considered of little value compared with excellence in design, proportion, and arrangement. This was especially the case when the drawings for a new type of engines had to be worked out, involving every kind of alteration as one's ideas became developed and matured, until at last perfection was arrived at as nearly as possible.

In the main engineer's office, to which I was attached, there were upwards of twenty draughtsmen and apprentices—English, Irish, Scotch, American and Brazilian, and, as the last named were foreigners, I must say a few words about them.

Eugénio Lopez de Gomensauro—whom we may call the head of the tribe—was elegant and refined in taste, and a remarkably pleasant little fellow besides. He was very anxious to learn, had apparently no faults, and, so far as we knew, no vices. He returned to his country, and, although his father was an admiral, his expectations were not realised as quickly as he wished, nevertheless, he subsequently held a good appointment.

Next in order came Antonio De Silva, a mild dispositioned, amiable youth. He was a hard student, and took care to read the best scientific books. A painstaking gentleman he was in what he liked, and what he did not care for he tried to avoid. Just before he left the works, he gave an evening party, to which we were

all invited, but as two of us, including myself, were absent, we were asked to dine with him at another time. When we arrived at the house, he received us in his shirt sleeves, made us heartily welcome, and then left us to take care of ourselves for a time. It turned out that he was cooking the dinner! but came in now and then to see how we were progressing. At last the feast was spread, all in good order, and to his own entire satisfaction, and altogether we spent a most pleasant evening. We lost sight of De Silva for many years, but at last it turned out that his studies had been pleasantly remunerative to him.

José Ferreira, another of the tribe, was as dark complexioned as if he had lived for many years under an African sun. He was a merry youth, took things very easily, and seemed to make the study of engineering a sort of elegant recreation. He used to place his drawing board on trestles, and, leaning back on his stool against a chest of drawers, looked the very picture of indolence and good humour when, with tongue lolling out of his mouth, he idly played with his instruments, and made personal remarks upon those around him. Ferreira also went home to Brazil, but not long afterwards revisited the old establishment, and, from what he said, it appeared as if the world had not treated him kindly. It is very apparent, however, that he must, somehow, have climbed the ladder of promotion, as I am told he latterly became a Government Official of High Degree in New York.

A sad event happened at this period to an English pupil named Billy Taylor, who was then amongst us. He was a fine, amiable, good looking, studious boy, one who promised well, and was a general favourite. On one occasion, however, *thirteen* of us, including Billy and myself sat down to dinner in a Birkenhead hotel, quite well and hearty. When our number was mentioned to him, he made some slighting remark, such as, "What did he care? He could eat his dinner just as well." Poor fellow! Within a fortnight we had the melancholy duty of laying him in his grave.

One or two of our drawing-office pupils seemed to consider engineering as a kind of stand-by amusement, and retired from the profession when their apprenticeship was out, and tried something else. They had a magnificent school of practice before them, and, if they had only availed themselves of it as they should have done, might have become, with fair opportunities, successful engineers.

In this respect, foreigners set us a very good example. They come here, to pick up as much as they can to take away with them. From this cause alone, a Frenchman in Napier's gave a great deal of trouble to the firm. He had been in some Continental technical school, and went to the Lancefield Works to study practice, which he did in the most persistent and audaciously appropriating style I ever heard of. The firm at last became tired of him, so he politely departed in accordance with their wishes. It may be mentioned,

however, that his people had given Mr. Napier large orders for ships and engines, which, of course, covered much that was disagreeable.

One of our frequent visitors during the time H.M.S. *Captain* was building was Mr. George Rock, her appointed chief engineer. He was "a fellow of infinite jest," and, as he was far on in years, put me much in mind of "King Cole," for he was just as merry. His relations had advised him to retire from the Navy, as he had been long enough in it, but he preferred staying a year or so longer in the service so that his pension might be increased. Not long afterwards, the ship sailed on her *last* cruise, taking with her Captain Cole, R.N., the inventor of the turret system, and poor George Rock also.

The foremen and workmen in Messrs. Laird Brothers' establishment were similar in character to those I knew so well at Denny's, but, having had little to do with either, I cannot say much about their peculiarities. Mr. Young, of the pattern shop, and Mr. Barton, of the erecting shop, were the two I saw most of, however. The former had been a long time in Maudslay's, and was a very fine specimen of his class, but, being somewhat aged, was generally called, in our office, "*Old* Young." In Smiles' "Life of James Nasmyth," the latter, while describing those associated with him at Patricroft, refers most kindly to his various foremen, who were such valuable assistants.

The chiefs of the executive have considerable respon-

sibility, as they stand between the masters and the men, and their object is to please the former by getting as much good work from the latter as possible, and, at the same time, to be kind, just, and not overbearing to them. Some foremen are very disagreeable and exacting, and cannot keep their "hands" if they can get employment elsewhere, as they dislike such overseers far more than bad masters, because they are always amongst them. When both, however, are good, the men take much greater interest in their work, and the result is a happy state of things all round.

In my early years, foremen had more to do in one sense than they have now, because first-class engineering firms get up their drawings so completely in every respect that the men work to them implicitly, whereas, long ago, a great many little details were left out of the plans to save expense in the office, and thus the foremen had often to use their own discretion in giving the necessary instructions to machine hands, fitters, etc., which caused considerable loss of time.

The former are simply good, steady, reliable workmen, advanced to a higher position. They have little or nothing to do with science, but are eminently practical in their respective branches, and, however accomplished an engineer may be, he can always learn something to his advantage in conference with these workshop lieutenants.

A thoroughly organised staff of foremen and workmen is of the utmost importance, as their complete

knowledge of the system adopted in the establishment to which they belong greatly facilitates the execution of a contract. This is fully recognised by the managers and partners of great firms, who often take orders at prices which will yield little profit, simply to keep the men together during dull times.

In large works, the foremen occupy a very comfortable position, are well paid, and have permanent employment, notwithstanding the changes induced by dull times. Mr. Barton and Mr. Young always wore dress hats, and were, therefore, the swell lieutenants of the Birkenhead Iron Works. Mr. Barton, however, had leading hands under him to take charge of each set of engines, and see that everything was well done.

Mr. Jones, of the machine shops and fitters, had, in the upstairs department, a forest of belts, drums, and pullies, to clear with his head, and to see that everything was made dead true to the drawings. Mr. Ashton, of the boilermakers, had many curiously curvilinear corners to calculate, consider, contemplate, and contend against in *his* part of the premises; and Mr. Williams, of the ship yard, had a great variety of cantankerously crooked crannies and crevices to crawl and creep into. These gentlemen were, therefore, obliged to be content with ordinary felt hats, which, in their respective cases, suited admirably. They all had their own idiosyncrasies of mind and manner. Any information, however, you wished from them at anytime, was kindly and pleasantly given, and everyone I

have named, as well as the others, knew exactly what had to be done, and how to do it to perfection.

In small factories, the foremen are required to assist in many ways, and are for this reason called "working foremen." In a Glasgow establishment, about fifty years ago, one of these overseers had taken on a "new hand," who soon afterwards asked for a file.

"What d'ye want a file for?" asked the chief.

"To file they j'ints."

"Weel," said the gaffer, "If ye canna mak' a j'int wi'oot filin'," or by mere *chipping*, "ye're no worth a big big D!"

In *very* small places, a foreman may be anything and everything in all departments, and get little for it too. He may also have to do the work with or without what we call "drawings"—a chalk sketch on a board or bench, or the point of an umbrella trailed over the dusty floor by the master, being often considered sufficient.

The engineer workmen in the Birkenhead Iron Works were steady and well-behaved, and, in this respect, much the same as those in similar places. The shipbuilders also conducted themselves satisfactorily; at least, during my stay of nearly nine years in their midst, I never heard of them acting indiscreetly at any time, which was very creditable to all concerned.

The character of the men of all ranks in any establishment only seems to follow the natural law of improvement by kind treatment from their superiors. Those, however, referred to in this chapter, may be

considered excellent specimens of a class which successfully executes some of the most important undertakings of modern times.

In conclusion, let me add a few remarks upon three of our most promising pupils, Philip Smith, Frederic Smith and Charley Blackburn, whom I have not yet noted.

Philip's father was a Church of England vicar of Leamington, and one of his brothers was travelling physician to the King of the Belgians, while he himself—a handsome and accomplished youth—was not only a lover of engineering, but a great admirer of the ladies, judging by the ease and artistic finish with which he could sketch beautiful faces from memory, while you talked to him.

Frederic Smith was a somewhat lean and hungry looking individual who had come to us from A-merry-ka, but, apparently not in a *merry-key*, as he evidently fed too much on science, and neglected his body. He was a devoted student of engineering, but, I rather think, imprudently burnt the midnight oil too far into the morning, and thus injured his constit*oo*tion. At any rate, poor Fred., as well as poor Philip—both of whom I shall ever charmingly remember—ended their days long before their brilliant hopes could possibly have been attained, which was a great pity, as those who strive to become walking encyclopædias of their profession *should* succeed in life.

Charley Blackburn was another very promising, and

genial, and happy, and acquisitive apprentice, who, after leaving Lairds', became chief draughtsman in the office of the Guion Steamship Company's works, and has been for some time past superintending engineer to the Isle of Man Steam Packet Company. Before long, he will no doubt be requested to similarly boss the fleet of some great Ocean Company to the satisfaction of everyone. I met him lately at a grand public dinner, when we had a most interesting talk about old times. I also discovered that he was still quite as popular as he had been in younger days.

I have referred somewhat fully to a few of my apprentice friends of the past, with the object of pointing a moral as well as adorning a tale, and the moral is this:—At one time influence alone helped many to positions they could not otherwise have attained. Now-a-days, however, good appointments are almost entirely dependent upon the experience of those who try for them, hence, it is most important for embryo "Eminents" in every profession so to lovingly and perseveringly master every little detail of their work as to be ready for promotion when the opportunity arises. Bearing in mind, however, that although none of us can command success we may all *deserve* it, especially if we use the best means to obtain it when they are at the immediate disposal of those who enter establishments such as the one just described.

CHAPTER V.

APPRENTICES IN THE WORKS.

Different kinds of Apprentices—How they get into the Works—Premiumed Pupils in England—The Scotch System—Advantages of each System—Marine Works—General Works—Special Works—Locomotive Works—Cause of False Steps in entering the Profession—History of Sir Edward Harland—Who should be Engineers—Workshop Practice, past and present—Suitable branches for Apprentices—Technical Schools and Colleges—Engineering Universities—McGill University, Montreal—Its Magnificence—Famous Works for learning Engineering—Various Classes of Apprentices—How treated—Special Electrical Works—Prospects of Engineers at Home and Abroad—Useful Hints—Repairing Works—Tools and Instruments needed—Working Dress.

I HAVE known very many apprentices, good, bad and indifferent, premiumed and free, in works and offices, some of whom no doubt hoped to occupy important positions in after life, although they had a strange way of qualifying themselves for such appointments. A few of those who paid entrance fees seemed to have a high opinion of the efficacy of their father's gold, and also a strong belief that the prestige of the great firm they were with would make their path to distinction smooth and easy. This was very complimentary, no doubt, both to the parents and to the eminent firm, but, as any earnest efforts on their own part to benefit by surround-

ing advantages seemed to be considered unnecessary, unhappy results usually followed which might have been avoided if proper care had been exercised in the choice of a profession.

Apprentices in the works are of a very miscellaneous description, and comprise the sons of noblemen, professional men of all ranks, commercial and manufacturing people, tradesmen and workmen; and the varieties of character are perhaps as comprehensive. Some are industrious, and some are not; some are well bred, and others are the reverse; some are enterprising and persevering in lines of thought and action too numerous to mention; some are witty, and others dull. In short, every class of society, and every shade of morals and disposition—the good and the worthless—are to be found among the youths of a great engineering establishment.

They obtain admission in three ways; firstly, by influence; secondly, by money; and, lastly, by both. The first system is exclusively adopted in Scotland, and the two latter are largely used in England, thus forming two distinct systems,—the premiumed and the free,—whose operations I shall endeavour to describe. In works on the Clyde, even of the highest celebrity, no premium is taken, and a boy gets into them because his father, or uncle, or some other relative or friend has given the firm orders for ships, engines, or machinery of any kind. Perhaps they have been otherwise useful, or may, indeed, from pure friendship, have a claim upon

the kind assistance of Messrs. So-and-So, who in cases of this kind will gladly do all they can.

Some engineers have so many friends of this description, that it is extremely difficult to find an opening in their works; and, as frequently happens in other pursuits, a long period may elapse between the application and the admission. On the other hand,—as I found it,—the latter may quickly and unexpectedly follow the former; at any rate, you must take your chance, and this applies even to places where premiums are accepted. Both systems, however, are defective.

In the first instance, a premium is paid to enable the pupil to obtain certain advantages which those who do *not* pay are not expected to possess. This is very fair; but, unfortunately, it opens out a serious evil that I have seen and known, which is injurious to the boy, and bad for every one concerned. When the youth thus begins his career, he is frequently treated too indulgently. He may work, or be idle; and may, indeed, be a source of annoyance to foremen and leading hands. And all this arises because perhaps £100 a year has been paid, which imposes too many restrictions on one side, and gives too much liberty on the other.

Having briefly described the English side of the apprentice question, I shall endeavour to treat that of the Scotch in a similar manner. In doing this, however, it may be stated that, although in early days some of their engineers accepted premiums, they now virtually say to intending pupils, "We'll take you if we

can, but you will have to work steadily and attentively, and behave yourselves properly, or we shall have to part with you."

So fully was this principle recognised and acted upon, that its results were highly beneficial, at least to those apprentices I was associated with in Denny's, Neilson's, and Tod & Macgregor's. In Denny's, for example, where I knew them best, they had an excellent character for steadiness and good conduct generally. They rarely lost even a quarter of an hour at 6 a.m.; they attended to their duties with much interest, and were hardly ever away except on special occasions, for which they obtained leave. We were a very healthy race, too, and seldom lost time from indisposition of any kind. We were a merry lot also, and got along pleasantly and happily, and some of us have done very well in various parts of the world.

Looking through the vista of many years which lies between the time I am now writing about and the present, I have every reason to speak favourably of those who were my contemporaries when an apprentice. This, however, I chiefly attribute to the excellent system adopted in the establishment, which, however, has since been much improved in various ways.

Napier's was a favourite place in those days, but they were very strict with their pupils, some of whom were dismissed because they did not attend properly, or were otherwise careless. The foreman's authority in this, as in all other establishments, was supreme, as it

is not considered etiquette for masters or managers to interfere with, or give directions to, men or boys. Machine hands, fitters, etc., were therefore discharged at a week's notice; and although apprentices could have been easily sent away for a time, they were not dismissed before a statement of the grievance had been made to the manager or principal, who alone decided what should be done. In practice this system worked admirably, and caused remarkable steadiness amongst those who, in after years, fully realised its advantages.

From what has been said, therefore, the whole question may appear simple enough. In other words, a youth pays for admission to the works, and, if an idler, may do what he pleases, and at the end of three or five years have only a very superficial knowledge indeed of that valuable practical branch of the profession he will never again have such an opportunity of acquiring. On the other hand, if he gets in without a premium, he will either have to do what he is told or cease to remain. In many cases this is certainly the best plan, but there is another aspect of the question which will be referred to elsewhere.

Having mentioned the disadvantages of the premium system, let me now shew the benefits it confers. In marine establishments the work is always changing. In the olden times this was especially the case, when no two orders were alike, and when every possible variety of paddle and screw engines were frequently being made. Even at the present day, when the triple and

quadruple expansion engines are almost universal, and the Parson's Steam Turbine machinery coming rapidly into favour, there are great variations constantly arising.

For instance, in some places, an order may come in at one time for a tiny pair of launch engines, and at another, for those of from 1,000 up to say 50,000 horse power in one set alone. This extreme diversity of size necessitates great alterations in design and construction to suit the ever changing circumstances of each particular case. Hence it will be seen that good Works of this description are among the best schools of engineering in existence, and often a source of fascinating study to those who practice in them.

To general engineering establishments a similar line of argument may be applied, but in places where a large quantity of special machinery of the repetition class is made, say for flax and cotton spinning and other textile manufactures, also steam winches, and a variety of small work which is got out rapidly and extensively, the men and boys are, by the division of labour system, turned more or less into automatons. They are kept, for a very indefinite period, turning this, planing that, and boring something else, also fitting up rods, valves, shaft and wheel work, etc., until completely wearied on account of the extreme monotony of their occupation.

In locomotive work, even at the best, there is too much sameness of description, and very little variety in size. For example, passenger and goods engines on our main lines have their cylinders generally from 16 to 18

inches diameter, and a large establishment may perhaps get an order for fifty of both sizes from India; not long afterwards forty more might similarly come in for Australian lines, and at another time a lot of compound engines for British railways. Thus involving an immense quantity of similar details which have to be executed by the system just mentioned.

That so many false steps are made in the choice of engineering as a profession, is attributable, on the one hand, to a want of proper knowledge of what is required of them by those who wish to enter it, and on the other hand, to unsuitability, or want of application, on the part of those who feel somewhat inclined to study it. The former is not to be wondered at, when we consider the private nature, generally speaking, of a vast amount of engineering employment. Of course there are great schemes, which everyone knows about, but there is also an immense variety of excellent practice constantly carried on, of which few, indeed, outside of the interested people, have any idea.

The error of judgment so many make in such matters, seems to be an idea that the practical and scientific branches are easily learnt: that drawing-office work is simple; and that, as a whole, neither energy nor patience is necessary. Never was there a greater mistake, as those who have been successful know well. Locomotive engineering may be comparatively easily learnt. Marine and Railway engineering each need a much longer time to acquire; but those who aim at

private practice, or foreign appointments, which throw men entirely on their own resources, and necessitate a thorough knowledge of many branches, will find that close and prolonged observation and study confer advantages of inestimable value.

If we study the lives of some of the great engineers, such as Watt, Fairbairn, Penn, Maudslay, Nasmyth, and others of much later date, we shall find that they owed their prosperity to innate energy, ability, and perseverance from first to last, and we might also add, the possession of that useful quality which enables people to make whatever they undertake a *pleasure* instead of a labour.

The history of the late Sir E. J. Harland is briefly given in Smiles's admirable book, *Men of Invention and Industry*. In a chapter written by himself, Sir Edward interestingly describes his apprenticeship in Stephenson's, at Newcastle, and his employment in the marine works of Messrs. J. & G. Thomson on the Clyde, as a draughtsman. After this we find him occupying the post of manager at Mr. Toward's on the Tyne, and soon afterwards at Belfast in a similar capacity until 1852, when he became sole proprietor, ultimately taking in Mr. Wolff—of Whitworth training—as partner.

The rise and progress of their immense establishment is given in detail, and throughout the narrative one cannot but see that Sir Edward's possession of all the qualities just named, during a long career, were fully rewarded.

Looked at broadly, engineering is so complicated in its higher ranges, and composed of such an infinite variety of details, the arrangement and proportions of which have to be carefully worked out, that we can only excuse indifferent students upon the supposition that they are financially independent, or that they really have no conception of what lies before them. In the latter case, however, the varied experiences of the author may possibly be found useful.

Some apprentices are born engineers; these need no comment, as they are quite able to look after themselves. Others are engineers by education, having, like myself, been obliged to take to it almost against their will. Whilst a few are totally unsuited for it. In my own case, however, a love of drawing proved invaluable, and enabled me at starting, and ever afterwards, to take a deep interest in all I saw relating to machinery, and it is this same taste for mechanical drawing which so often indicates those who, with fair opportunities, are likely to succeed in the profession.

Forty years ago, workshop practice was very different indeed from what it is now, as a great amount of time was spent in acquiring sufficient manual dexterity for the proper execution of difficult and important parts. Now-a-days machinery does almost everything, and thus practical instruction has been robbed of most of its charms. If a youth, therefore, is content to remain as a workman, and take the very remote chance of being a foreman, the training he now

receives will be sufficient for the purpose; but for those who aim at higher positions, their whole future hangs upon a thorough knowledge of the scientific branches practised in the drawing-office.

In view of all this, the best plan appears to be to send the ambitious ones from three to five years to good marine, locomotive, railway, general engineering or electrical engineering works, according to circumstances, and let them have the run of the pattern shop, machine shop, fitting and erecting shops, and drawing office to finish with. Even if the latter cannot be obtained, there are many avenues to scientific knowledge utterly unknown "when I was a lad."

These consist of Technical Schools where evening classes for various sciences are held for the benefit of students who feel inclined to spend one or more evenings per week in this manner. One of the best of these is the Central Municipal Technical School of Liverpool, which, from a small beginning many years ago, has now become a magnificent and handsomely appointed new building. Having occupied the post of honorary treasurer for some years in the past, I am well acquainted with the long-sustained usefulness of this Institution, and its now enormously extended sphere of operation on lines of practical thought.

The University of Liverpool is a splendid Institution for the education of "Cub Engineers," as the Americans term them, and where, under the judicious supervision of highly accomplished professors, the

youths are carefully trained in the various practical and scientific branches of engineering, filling up their spare time, under University auspices, in the summer, by going into the workshops of good establishments where they can take part in real practice on, it may be, a colossal scale.

So far as schools, colleges, and universities are concerned, those named indicate pretty clearly the systems more or less adopted in others throughout this country. The finest I have seen, however, is that of McGill University, Montreal, which, during a recent tour throughout Canada, I had the privilege of carefully inspecting under the kind favour of Dr. Henry T. Bovey, M.A., D.C.L., LL.D., F.R.S., M.Inst.C.E., and Dean of the Faculty of Applied Science.

The origin of this scheme dates back to the year 1813, when the Hon. James McGill, a wealthy citizen of Montreal, presented a sum of £30,000, with the object of founding a centre of education for Canada, the buildings for which were soon afterwards commenced. Through the subsequent liberality of many other gentlemen, including Sir William C. McDonald, the University has been extended, step by step, until it has now assumed very large dimensions. Not only are the buildings of handsome architectural design, and lime-stone construction, and situated amongst lovely surroundings, but their interiors are lavishly fitted up with every machine and appliance and apparatus which can enable students to learn their profession to the best

advantage. Some idea of the popularity of "McGill," as it is frequently termed, may be gathered from the fact that, from first to last, Sir William alone has presented it with about three million dollars.

During my stay in Montreal I had the pleasure of being interviewed by one of the staff of the *Montreal Witness*, in the usual exhaustive American style. This gentleman wished to know *everything*, namely, my antecedents, place of birth, age—"somewhere about"—object of my visit to Canada, my opinions of, and suggested improvements in, the city, and everything else, indeed, which he thought might interest the people about whose Dominion the "chiel' had come to tak' notes." The result being a very complimentary whole column article which did him great credit.

So far as the works *alone* are concerned, there are many very fine establishments throughout the British Isles to which I could refer if space allowed; it is, however, only right to mention that, although few firms take much interest in their apprentices, those who are fortunate enough to gain admission to some of the establishments previously described, as well as others named on later pages, will find themselves carefully looked after from every point of view.

One of the best illustrations of the English premium system is to be found in the Queen's Engineering Works of Messrs. W. H. Allen, Son & Co., in the pretty little town of Bedford, to which they removed

from London in 1894, after building new general and electrical engineering works, admirably equipped with the most improved labour-saving machinery and systems of construction.

There are various classes of apprentices in this establishment, ranging from the five year, third-class boy of the admission age of 15 to 16, who learns only one branch, to the privileged three to four year pupil of 17 to 21, who learns five branches, including drawing-office practice. In this case, however, the premium is at the rate of 100 guineas per annum, the advantages consisting of systematic training under the careful supervision of the principals and foremen, and encouragement to win annual prizes of 25 to 50 guineas for general good conduct, punctuality in attendance, and ability, progress, and interest shown in their various occupations. Besides this, employment is given upon outside contracts of the company, and also on a salary when the pupilage expires.

It may be added that only youths are accepted who evince a keen interest in engineering, have passed a strict medical examination, and are willing to adhere to the rules of the establishment. To ensure all this, however, they have to pass a probationary term of one to three months in the works before their indentures will be signed, which is very good for all concerned.

There are many purely electrical establishments throughout the country, sometimes of immense size, where apprentices do well, but the Falcon Works of the

Brush Electrical Engineering Company, at Loughborough, have been brought specially to my notice. They were founded by the talented Mr. Charles F. Brush—the originator of the electric arc lighting industry of the world, in which multi-millions of pounds are now invested—and whose firm organised and equipped, on the most perfect modern lines of thought and practice, the new works just named, where pupils receive the best theoretical and practical instruction in various branches during a term of three years, at the rate of 100 guineas a year, which is about the usual premium in good establishments. Full particulars of all of these, however, as well as of the special advantages they individually offer to *apprentices*, need not here be given, as they can otherwise be much better obtained.

By means of the various avenues to knowledge just mentioned, a large amount of valuable information may be acquired by earnest students which will greatly assist them and extensively enlarge their future prospects.

These prospects are not so encouraging as they once were, but, although the British Isles may be overdone in this respect, engineering enterprise is extending so rapidly abroad that many good appointments are to be had in other lands for those who are capable of holding them. An excellent thing to observe in life is—Do not wait until your rich relations—if you have any—or your poor, but kind, friends help you out of a difficulty. Act for yourself with all the power and ability you

possess, and they will think all the more of you for doing so, and be more inclined to give their aid.

If you cannot command the winds, you can spread the sails, and well-directed and sustained efforts are generally rewarded in some form or other, and frequently in the most unexpected manner. The art, therefore, of doing as much as possible for one's self is highly to be commended, and especially so because some of the most eminent men in the various walks of life have, in this respect at least, been most diligent.

Said a lady to me one day: "The So-and-So's have got their son into the engineering establishment at Blanquetown, without paying any premium, and they are giving him six shillings a week to begin with!"

"Quite right, madam," I replied, "he may well have such liberal treatment, because he is only in *Repairing* Works, where he will not learn much."

So it was, and is, and ever will be in such places, so long as they are what they are. With the exception of the Crewe Works, and others of similar nature, where, in addition to continuous repairs, they make their own locomotives and a great deal of other fresh work, there is really nothing that an ambitious apprentice need trouble himself with. The reason is this:—In these establishments the work is connected with damaged, worn, or broken details, which may have been long in use, and require renewal in some form or other. Pins of various sizes have to be turned, new brasses fitted, valves of different kinds rectified, the working gear

needs touching up in various places, broken framings want patching, and so on to the end, amidst greasy dirt of the most atrocious nature. The patterns are very limited in number, and the drawings just what might be expected when no new machinery is designed.

Hence, for all these reasons, a repairing shop is in every respect the worst possible school of thought and practice a youth can enter. People generally do not know this, and the poorer members of the aristocracy are quite ignorant of it, fancying all the time that their sons are highly favoured by being admitted for nothing to what they consider a great "engineering establishment," and getting, besides, the sum of six shillings or more per week for their valued services.

Those who enter the Pattern shop anywhere must provide themselves with a chest of tools for working in wood, which may be had for about £6, but in the iron departments, files, chisels, hammers, and all other appliances, are supplied by the firm. In the drawing office, however, every one needs to have his own instruments, that is, a 36-inch ebony-edged tee square; one ditto 45° set square, 8 inches long, and another of 60°, 10 inches in length; two oval section 18-inch boxwood scales, one of which will be divided to $\frac{1}{8}''$, $\frac{1}{4}''$, $\frac{1}{2}''$, and 1″ to the foot, and the other similarly to $\frac{3}{8}''$, $\frac{3}{4}''$, $1\frac{1}{2}''$ and 3 inches. An H.H.H. pencil, a good piece of vulcanised indiarubber, and, say, three or four good colour brushes will complete the outfit. The most important thing, however, is a box of instruments of first-class quality,

and of book form for conveniently carrying in the pocket, the cost of which need not exceed £3 or so.

The best place for obtaining the squares and scales above mentioned, is Mr. W. F. Stanley's, Great Turnstile, Holborn, London, which I can confidently recommend, having long used his productions, and supplied them in every case to my own numerous pupils. Indeed, I may, to use a well known but amended quotation, say of this gentleman—"I used your instruments thirty years ago, since when I have used no other."

The dress of the engineer should be of the simplest character, and of good navy blue serge and white duck. The latter is very useful in the form of "overalls," as it can be so easily washed. Especial care, must, however, be taken when ordering a suit, as the tailor, having in view the fashionable style of trousers, breeks, or galligaskins, will probably not allow sufficient for future shrinkage, and thus cause considerable discomfort afterwards, not to mention the attenuated appearance they will certainly give to the legs of their unhappy wearers.

CHAPTER VI.

WORKS OF THE LONDON AND NORTH-WESTERN RAILWAY COMPANY AT CREWE.

Their unique Attractions for Visitors—Universal Scope of Operations—Immense Proportions of the Works—How the safety of the Public is insured — Engineers-in-Chief, past and present — Arrangement of Buildings — The *Steel Works* and their Surroundings—Treatment of Ingots—*Rolling Mill* operations — Manufacture of Steel Rails — Weldless Wheel Tyre Process—The *Steel and Iron Forges*—Their heavy Machinery—Hydraulic Forging Presses — Forge Stamping Process — Forging Machines for rapid repetition work — Diversified applications of Hydraulic Power—Its extreme handiness—The Accumulator and its uses—Three ton per square inch Pumps—Hydraulic Lifting Appliances—How Scrap Cuttings are utilised—Gas fired Works—Value of the Gas-firing system.

As all railways more or less owe their successful management and maintenance to the Works where their renewals and repairs are executed, let me now describe a model establishment of this class, which is the largest in the world, and which has long been considered of unique interest by royal and distinguished personages who have visited this country, and by engineers and railway officials from all parts of the globe. The following description, however, is also intended to give a good idea of what, to some extent, takes place in other works of similar nature though of lesser degree

If the vast establishment at Crewe merely constructed as well as repaired the engines and rolling stock of the line, it would be similar to many others, but when the manufacture of *materials*, and of every *mechanical appliance* connected with railways is added, it will be evident that these works stand alone. By the italicised terms are meant steel as a metal, rails, chairs, and sleepers for the permanent way—plates, bars, and angle, etc., irons, for engine frames, boilers, tenders, ships, bridges, and so on—mill gearing, and engines of all kinds for the outside and inside requirements of the various lines—signalling apparatus—steel and iron castings of every description—brass founding and copper work—timber work on an extensive scale—and every thing else, indeed, which can in any way advance the engineering interests of the London and North-Western system.

As may readily be supposed, the workshops in which the above operations are conducted require a large amount of space. This may be gathered from the fact that while some of our largest private establishments occupy 50, 60, and even 70 acres of land, the Crewe Works require a much larger area, and this, too, notwithstanding the existence of large wagon works at Earlestown, and carriage works at Wolverton, besides minor repairing shops at Willesden, Rugby, Carlisle, and Longsight, all of which, however, receive their iron and steel from Crewe.

These remarks will give a fair conception of the

gigantic series of operations carried out at the establishment I had the pleasure of critically surveying, through the kind permission of Mr. F. W. Webb, the late chief mechanical engineer, aided by kind information specially supplied for this volume by his succsssor, Mr. George Whale.

As the latest and best means are employed for maintaining, in efficient order, the system just named, over which some of the heaviest and most continuous traffic of the world is carried with *marvellous safety*, it was necessary thus to gather important facts. As this italicised term, however, may convey a false impression regarding the necessity for so many renewals and repairs, owing to the almost entire absence of severe accidents, it must be remembered that so highly pressed has everything now become on railways, that the ordinary wear and tear of every-day traffic is quite enough in itself to keep the Crewe and the other establishments fully occupied.

Further, it may be said, that a very large amount of the employment so continuously given to these works, is created by a principle which permeates the whole of Engineering practice on land and sea, and which requires the immediate expulsion of every faulty part *before* it breaks and does mischief. Hence it happens that cracked tyres; crank axles that look unsound; boilers that need repairs; valve faces that require planing; cylinders that want re-boring; bearings of all kinds that need re-adjustment; rods that have been

damaged; not to mention all the minor details of the rolling stock and fixed plant, and everything else connected with the permanent way and its fixings, etc., throughout the whole system, which have to be repaired and renewed, in addition to the new engines, tenders, and other matters constantly in hand, for fully 3,000 miles of double, and frequently quadruple line, will at once account for the immense proportions of the Works at Crewe.

From 1830 to 1842, the extension of the railway system in England was astonishingly rapid, but in the latter year, the Liverpool and Manchester, the Manchester and Birmingham, the London and Birmingham, and other lines, including the Grand Junction, became united in one comprehensive Association entitled the "*London and North-Western Railway Company*," which soon afterwards realised the importance of selecting a central point for conducting its various operations. In 1843, therefore, the Grand Junction Repairing Works, which up to this period had existed at Liverpool, were transferred to the village of Crewe, which has, since then, advanced by leaps and bounds from a population of 203 in 1841, to one of about 45,000 at the present time.

In 1843, the works covered not quite three acres of ground, now, however, with recent extensions, they are one and a half miles in length, and occupy an area of 137 acres. At present they employ nearly 8,000 men, not including fully 700 engine drivers, and in addition to

these, a large number of hands connected with the line are located in the district, the total number employed by the Company over its whole system being about 70,000.

The first Locomotive Superintendent at Crewe was a son of Mr. Trevithick, who was succeeded in the year 1857 by the late Mr. Ramsbottom. In 1871, the post of Chief Mechanical Engineer and Locomotive Superintendent became occupied by Mr. F. W. Webb, who, after directing for some years the Bolton Iron and Steel Works, returned to the establishment in which he had formerly been *apprentice* and latterly acted as *manager*, and where he subsequently introduced many useful patents.

As the main parts of the buildings are of recent erection, every attention has been paid to their arrangement, which has provided for greater proportionate area, better light, the best methods of lifting and transporting heavy weights, and also a simple and pleasing style of brick and stone architecture.

The *General Offices* are of the most spacious description, and occupy a handsome building two stories in height, and 525 feet in length, embellished with evergreens, which, along with an adjacent shrubbery, produce a very picturesque effect. The above contain the Drawing Offices; the Accountant's and Commercial, etc., Offices; the Running and Signal Offices; the Photographic Studio and Laboratory, etc., and the private rooms of Mr. Whale and the numerous heads

of departments. Here, too, full occupation is found for hundreds of draughtsmen, clerks, and others, who are engaged not only in the scientific and commercial branches, but in keeping exact practical records of engine performances, coal consumption, works expenses, etc., and the general expenditure connected with the building, repair, and cost of working and maintenance, of all the engines and machines throughout the whole system.

Everything is done in regular order, even to the guidance of a visitor over the premises. In this way, kindly escorted by one of the officials, we passed from shop to shop, the first department being the *Bessemer Steel Works*, where the manufacture of steel is carried out in all its completeness. This proved specially interesting, owing to the employment of a class of machinery not to be found in any other railway establishment, as that of Crewe is the only one which rolls its own rails, plates, bars, etc. Here we found a profusion of wheels, tyres, axles, and other miscellaneous gear in the rough state, ready for the various machining operations.

Having no wish to tire the reader by entering upon such a severely technical subject as the methods employed for producing 50,000 tons of liquid steel per annum, let me only say that after this fluid has been run into large ladles, it is poured into moulds where ingots of the required size are cast. When these have sufficiently cooled to enable them to be taken out of the

moulds, they are re-heated previous to being passed on to the *Cogging Mill* to be roughly trimmed in size, and then taken to the *Rolling Mill*, where, with great speed and exactness, they are rolled into plates, bars, rails, etc., of specified sections and weight per foot.

The *Rail Mill* at Crewe is one of the most important sections of the works, as it contains machinery capable of manufacturing 45,000 tons of rails per annum. Broadly speaking, Rolling Mills consist of two distinct classes—those for plates, and those for bars. The former consist of rolls whose distance apart is so regulated by screw gear that a few passes of the plate between them gradually reduce it to the required thickness.

Bar rolls are of endless variety to suit angle, tee, channel, etc., irons, and also rails, which at Crewe are in great demand for extensions as well as for old lines. Here, however, each pair of rolls is grooved to suit the different stages of manufacture, beginning with the original billet, and ending with the finished production.

The manufacture of Rails at Crewe is most instructive and interesting, and with the mills driven at high speed by powerful engines, an ingot about 3′ 4″ long by 14″ square, is rapidly reduced in the roughing rolls and completed in the finishing rolls as a 60 feet rail, weighing 90 pounds per yard. Upon leaving the mill it is carried over a series of live rollers to a *Hot Steel Saw*, which cuts it to the length required to allow for contraction in cooling to the exact dimensions. Subse-

quently, the rail is straightened, and passed on to a duplex machine, which accurately drills the fish-plate bolt holes at one operation.

Having described the manufacture of steel rails, let us now turn to that of the *Wheel Tyres* which run upon them, and which differ very materially from the original welded iron hoops. Noting the defects of this system, Mr. Ramsbottom conceived the happy idea of manufacturing *weldless* tyres of Bessemer steel. The process, as it stands to-day, is so simple and effective, that by means of special machinery immense quantities of faultless tyres up to 8′ 9″ diameter are produced with an economy otherwise unattainable. The quality of the metal, too, is so much improved by the manipulation it undergoes that it is enabled to withstand satisfactorily the most severe tests.

A visit to the neighbouring *Steel Forge* is most instructive, as it contains so much powerful machinery. This includes two massive hydraulic Forging Presses; four steam hammers ranging from 50 cwts. to 8 tons; plate, axle, and tyre mills; various heavy punching and shearing machines; twenty hydraulic and hand power cranes, etc.; and two 7′ 0″ diameter circular saws for hot metal, either of which, with a peripheral speed of 13,000 feet per minute, will cut through a 9″ axle in about half a minute.

Another *Forge*, in the Old Works, is employed on much lighter work, including amongst its ordinary occupations the *stamping*, by means of "Drop" Ham-

mers, of immense quantities of details of all kinds, which can thus be much more cheaply and more accurately made than by the hand labour system.

The *Lever Punching and Shearing Machine*, shown in the next illustration, is capable of operating upon plates up to $1\frac{1}{4}''$ thick, and angle irons up to 6″ by 6″ by $\frac{7}{8}''$. It can also be employed for cutting, in perforated postage stamp fashion, variously shaped apertures in plates, or in punching them out solidly when required. Many other extremely useful varieties of this class of machine are employed for general purposes.

After everything had been done to develop the steam hammer to the utmost, it still proved incapable of making multitudes of small details with the desired speed, or the heaviest forgings with sufficient internal soundness. Hence it has been superseded by special machinery for the former, and by 1,000 to 14,000 ton hydraulic presses for the latter.

The first-named operations are performed by means of *Forging Machines*, which are fitted with a series of hammers so graduated in form as to produce unerringly and with great rapidity the required details, the hammers being worked by eccentrics on the main shaft at a speed of about 600 revolutions per minute. The bottom blocks, or anvils, are adjustable vertically to such an extent that forgings, in large quantities, can be automatically finished to an exact size with the least amount of trouble.

For very heavy work, the *Hydraulic Forging Press* is

LEVER PUNCHING AND SHEARING MACHINE FOR PLATES AND ANGLE IRONS.

most successfully employed, its usefulness depending chiefly upon the fact that the pressure is so severe, and so steady throughout, when compared with the more superficial action of the steam hammer, that the whole mass of an enormous ingot is thoroughly consolidated.

The incidental advantages of the press over the steam hammer for heavy forging are very great. Firstly, the blow does not affect the surrounding buildings nor even the shop in which it is placed, whilst, at the same time, little foundation is required. The press is noiseless and exact in its action, and although primarily made for *forging* purposes, can be easily employed in stamping, straightening, bending, cutting, and punching, the water used in working being otherwise available by means of a simple arrangement of valves and pipes.

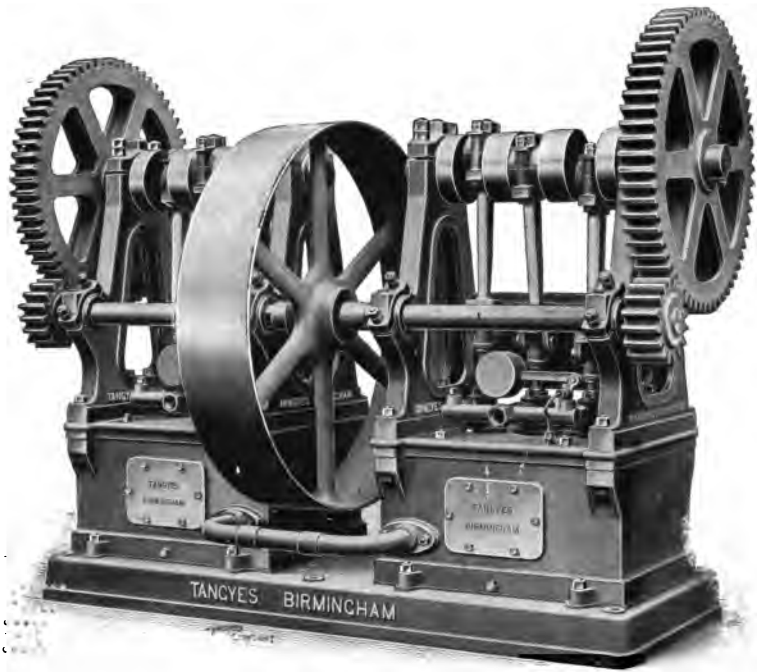
Amongst its numerous advantages may be mentioned the great amount of work that can be done at one heat, thus saving labour and fuel; the superior uniformity in the quality of the material thus produced, and the absence of shocks to the structure which enables it to work a long time without repair. Although the working pressures usually range from 750 to 1500 pounds per square inch, those of 300 to 400 pounds can be conveniently arranged for. Recent machines have, however, used pressures up to as much as 4 tons per square inch when required for other purposes.

For a considerable time after Bramah's famous invention, the art of using water power continued in a

backward state, as the time occupied in producing great pressures was much too long, and the operation far too expensive and cumbrous for general use. To overcome this difficulty Sir William Armstrong invented the *Accumulator*, which immediately opened out a very wide field for the economical application of greatly intensified and concentrated water power. The beauty of this system lies in the fact that it stores up the energy supplied to it by comparatively small pumping machinery, and lets off this power, not only instantaneously, but in an extremely convenient manner, to points perhaps miles distant. Particularly is this the case with regard to the working of gates, cranes, swing bridges, etc., over the whole area of a vast dock estate, the water being conveyed underground by means of pipes, just as it is being similarly done on a gigantic scale in cities and towns for the use of the inhabitants.

Nowhere in the realms of engineering does the *Hydraulic Pumping Engine* occupy so unique and indispensable a position as in this species of work, where its leading features consist of relatively small plunger pumps, and immensely strong parts to enable it to withstand the enormous pressure previously mentioned. There are many sizes and arrangements of these pumps, vertical and horizontal, with single acting and double acting rams, actuated by steam cylinders, sometimes of great power, or by electricity, to suit the ever varying circumstances of modern practice.

One of the principles so happily utilised in hydraulic



COUPLED HYDRAULIC THREE-THROW THREE TONS PER SQUARE INCH PRESSURE PUMP.

machinery is that when subjected to pressure it transmits it equally in all directions. Hence it follows, that a pressure of say one ton per square inch, applied by a rapidly moving and small pump ram, is at once transmitted through pipes to the ram chamber of the more or less heavily loaded accumulator, and from that to any desired spot. The fluid power thus produced transmits energy in every possible direction, angularly, curvilinearly, and undulatingly, over great distances, with only a trifling loss of efficiency. The Plate opposite page 88 illustrates an arrangement of *Duplex Three Throw Pumps*, capable of working at a pressure of three tons per square inch, the water being discharged through the pipes shown in the view.

Amongst the innumerable minor applications of hydraulic power in railway practice may be mentioned the taking off or putting on of engine, carriage and wagon wheels, etc., otherwise of very inconvenient accomplishment.

The plate opposite page 90 shows how this is done by means of Messrs. Tangye's *Portable Wheel Press*, the hand lever pump being worked by an attendant until the wheel is—in this case—pulled off the axle; the long bars being used with slight modification for pulling it on with the required tightness, which is indicated by the pressure gauge.

The last application of hydraulic power which will here be given is illustrated in a view of a 25 ton locomotive end lifting *Hydraulic Gantry*, by Messrs. Tangye,

shown opposite page 92. This type of gantry is very extensively used in outside works, sometimes of the most colossal nature, and for carrying enormous weights. Its value may be gathered from the fact that it sweeps the whole line for any required distance, and is conveniently worked by hand pumps; the piston rod, crosshead, and multiple chain pulleys indicating an arrangement which permeates the realms of hydraulic lifting appliances, since a small stroke of the piston causes a greatly increased traverse at the lifting end.

Examples sufficient to fill many volumes might be given as illustrations of the Statical and Dynamical application, in countless forms, of one of the mightiest, most comprehensively useful, and most economical of all the forces of Nature. Here, however, enough may have been said to give the reader a mere glance at a branch of fascinating practice which enters more or less into the every-day life of an engineer.

In the Forge portion of the works just described, all the scrap cuttings of wrought iron and steel collected throughout the establishment are re-worked, after being thoroughly cleaned by rubbing against each other in revolving cylinders, so that not only is there no waste, but a *better* material is obtained. Here, too, some of the specially designed heavy shearing machines are to be found which cut into pieces old rails, tyres, boilers, etc., for the above purpose.

It may be noted that in the above Steel and Iron Working Departments, as well as in other portions of

PORTABLE WHEEL PRESS, FOR TAKING WHEELS OFF OR FOR PUTTING THEM ON THEIR AXLES.

the establishment, the metals are heated in gas furnaces, the vapour of which is generated in 51 gas producers, and then led to the former by means of underground pipes. By this method, the surrounding atmosphere is kept free of smoke.

The value of this *Gas-firing System*, from an all-round point of view, may be gathered from the fact that it is not only very extensively used for heating purposes of every description, but as a chief motive power for gas engines, etc. To provide for the vast requirements of the public, the Power-Gas Corporation of London have a large establishment, at Stockton-on-Tees, for the construction of gas manufacturing plant, which has been very extensively supplied to some of the largest engineering and other works at home and abroad.

The special advantages of this gas include the employment of the cheapest quality of coal, namely, slack or dross; the small amount of labour required for its production, and its great heating value. The cost, when produced on a large scale, is less than one halfpenny per 1,000 cubic feet, 60 of which are required to produce—in large gas engines—one indicated horse power per hour, the value of which will be clearly seen when applied to engines which now range up to 5,000 horse power. Amongst its other advantages may be mentioned the extremely high temperatures which can be obtained by employing regeneration, and also, that for metallurgical purposes it is an ideal gas.

CHAPTER VII.

MANUFACTURE OF RAILWAY PLANT AND MACHINERY ON A GIGANTIC SCALE AT THE CREWE WORKS.

Peculiarities of the *Boiler Department*—The Music of the Works—Perplexities of Boiler Practice—How they effect Public Safety—Failures of early Steel Boilers—First Steel Locomotive Boiler—Its effect upon subsequent Practice—Hydraulic Machinery—Its various Applications—Unique Advantages—Water Tube Boilers—Improvements—The *Iron Foundry*—Preparation of Patterns—Foundry by Night—A Weird Scene—How to ensure Sound Castings—Preparation of Moulds for Castings—Rapid Machine Moulding for Repetition Work—Sand Blast Apparatus and its Uses—Cupola for Melting Iron—*Brass Foundry*—Peculiarities of Brass—Magnetic Treatment of Waste Cuttings.

In the course of our rambles through the above Works, we came to the *Boiler Shop*, which is 673 feet long by 108 feet in width, where we found this most important detail in every stage of construction or repair. Although this department is necessarily much larger than those of locomotive establishments in general, it does not vary materially from them in general arrangement. The main difference, however, lies in the fact that while in the latter only new work is executed, in the former the repairs and manufacture of all the boilers for the whole of the London and North-

HYDRAULIC GANTRY.

Western system are constantly progressing. This will at once account for its very spacious dimensions, which enable it to turn out annually about 200 new boilers, and execute the repairs for those of 3,000 locomotives besides. And this, too, quite apart from the similar though much lighter work of the immense adjacent *Tender Shop*.

As we entered this portion of the premises it became evident that however much hydraulic riveting machines may be used for boiler shells, etc., there is, nevertheless, a large amount of work which, for convenience, is still done by hand.

The *Music of the Works* is peculiar in various ways. We have, for example, the *thump—bang*—SMASH staccato movements of the steam hammers, and the magnificently illuminated fortissimo music of the hot steel saws. The ring of the sledge-hammer upon the blacksmith's anvil is so beautiful that it has been most effectively reproduced in instrumental performances. The *buzz*-cum-*swish*-cum-WHIRR movements of the wood-working machinery; the pianissimo cadences of well ordered lathes, or the exquisitely smooth action of the cold steel sawing machines; the concord of more or less sweet sounds in the finished machine departments generally, with the hum and soft noises of their multitudinous drums, pulleys, belts, etc., as they perform *their* portion of the programme to absolute perfection, taken as a whole, cannot fail to deeply interest all who view those scenes.

When, however, we enter the boiler shop, our ears are assailed with machinery music, sledge-hammer music, and with a deafening outburst of sound produced by hand riveting. In addition to the boilers named, numbers of others for various purposes are here built and repaired; also large quantities of steel girders of all kinds for warehouses, roofs, bridges, etc., are made.

Were we to refer to the *generation of steam* in land and marine boilers of the present day, we would approach a subject that has been most ably discussed from every point of view by many of the most advanced scientists of the age. The wonder is that in the interior of a plated shell — in the chemistry of the water that partially fills it—in the heat that evaporates this fluid—and in the mechanical and structural peculiarities of the whole fabric, including its management in practice, there should have existed so much that was perplexing. So immensely important is this subject, that it has severely taxed the best resources, mentally, physically, and financially, of many of the most profound thinkers and most skilful inventors.

If any ordinary visitor to a boiler shop, such as that now under consideration, were asked what he or she could see in the hollow shell which rounds the fire that boils the water, which produces the steam that drives not only locomotives, but even the most colossal engines ever built, the answer would be "*nothing*."

And yet, without these simple looking boilers, the finest steam machinery in the world would lie like a

log—dead; and without the most exhaustive care and skill in their design, construction and maintenance, such stupendous disasters on land and sea would be so continually occurring that people would be glad to return to the old stage coach and sailing vessel, rather than risk their lives in steamships or in railway trains, even of the twentieth century.

At this point it may be well to state that, up to the end of 1872, the numerous attempts that had been made to introduce steel into the manufacture of boilers had proved failures, but at the International Exhibition in Vienna, in 1873, a locomotive boiler of this material was sent from the Crewe works. This was a very fine specimen of advanced practice, and since that time immense numbers of locomotive and stationary boilers have been thus made at these works without a single failure having occurred. It may be mentioned, however, that the greatest possible care is taken to obtain trustworthy plates, a piece being cut from each and subjected to the most severe tests of every kind, which are registered for future reference.

In this department is to be found a large and varied collection of machines for punching, shearing, planing, bending, drilling, flanging, riveting, etc., some of which are described elsewhere. Although the *drilling* of rivet holes in boiler shells may appear to be quite as necessary at Crewe as at any other establishment where boilers are constructed, they are nevertheless *punched*. This fact alone, after all that has been said

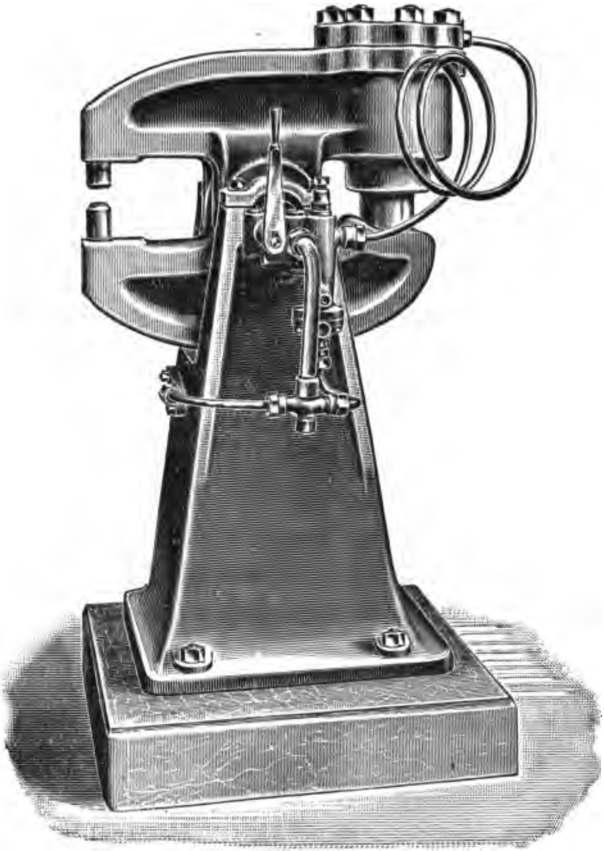
and written in favour of drilling for years past, will no doubt be interesting to many, as the employment of an apparently obsolete custom is due chiefly to improvements in the manipulative processes.

The rivet holes in all London and North-Western boilers are punched in a machine which has an automatic and pitch-adjustable feed arrangement that enables it to perforate the holes precisely the same distance apart throughout. By having the die a little larger than the punch, these holes are made slightly tapered, instead of being parallel, the two plates to be riveted together being placed with the smallest diameters of the holes next each other, thus ensuring the entire filling of the aperture by the rivet.

In the circumferential joints, where only two plates lap over each other, the holes are not reamered, but in the longitudinal joints, where there are three thicknesses of plate, the holes in the middle one are punched a little smaller than the rivet, and afterwards reamered parallel and hydraulically riveted.

The adjacent illustration of a patent improved *Riveting Machine*, by Messrs. Henry Berry & Co., of Leeds, gives a good idea of the manner in which this motive power is applied, and clearly shows its principle of action, not only in machines of immense size, but also in the great variety of smaller ones—portable and fixed—which permeate the realms of practical engineering. This machine has a top ram—as shown—and also a bottom ram, both of which are acted upon by the

fluid, and when giving out its full pressure of 50 tons, is able to finish off rivets up to 1″ diameter.



HYDRAULIC RIVETING MACHINE.

An example, by the same firm, of a *Portable Hydraulic Punching Machine* for holes up to 1″ diameter,

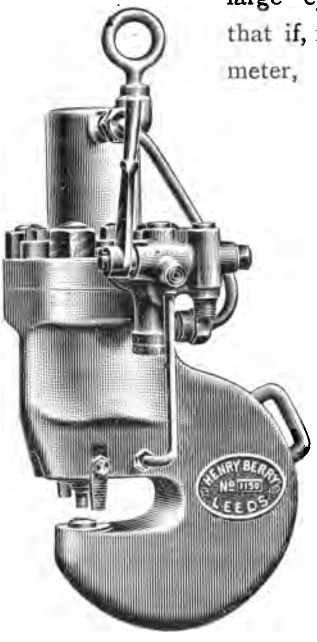
through $\frac{5}{8}''$ plates, is shown on next page. It also illustrates, to some extent, the manner in which punching and riveting machines of this class can be adapted to work in any position when slung by a rope, or otherwise, even in confined spaces. An excellent feature of this machine is that, by means of Messrs. Berry's patent automatic *Intensifying Valve*, full power is only given out when required, thus saving weight and expenditure of water.

As one who for a long period has witnessed many of the changes that have occurred in engineering practice, we cannot but greatly admire the system of hydraulic machinery which has been so successfully developed by many inventors as to make it capable of world-wide application, especially in cases where no other motive power can be economically employed.

To the non-professional, there is something mysterious in the ease and silence with which the most extraordinary performances are accomplished, without any assistance whatever from the wheels, pulleys, bevel and spur gearing, etc., to which, in other machinery, so much importance is generally attached.

Is there not something very like Hindoo jugglery in the way in which a gigantic cold or mildly hot steel armour plate is bent as noiselessly as the fall of a leaf, not to mention the snipping of massive rails or tyres, etc., as if they had been so much cheese, or the similar punching at one stroke of oval apertures, up to, say, 30″ by 21″, in one inch steel plates—all cold ?

These apparent mysteries are due, firstly, to the almost incompressible nature of water, and, secondly, to the ease with which it may be forced, under tons of pressure per square inch, through small pipes into a large cylinder. Hence it follows that if, for example, a pipe $1\frac{1}{8}''$ diameter, or one square inch area, discharges water at a two ton pressure into a cylinder $25\frac{1}{4}''$ diameter, or 500 square inches area, we have at once a bending, crushing, or lifting power of 1,000 tons, not only with wonderful compactness and extremely smooth action, but with a safety absolutely unique, as a pipe, etc., *harmlessly* bursts, whereas, with *steam*, death and destruction might be scattered around. This, then, is the secret of the popularity of the power just described.



PORTABLE HYDRAULIC PUNCHING MACHINE.

No branch of engineering has been more frequently and carefully surveyed and reported upon, and, in its marine forms, condemned and approved, officially, by various "Eminents," and apparently perfected by

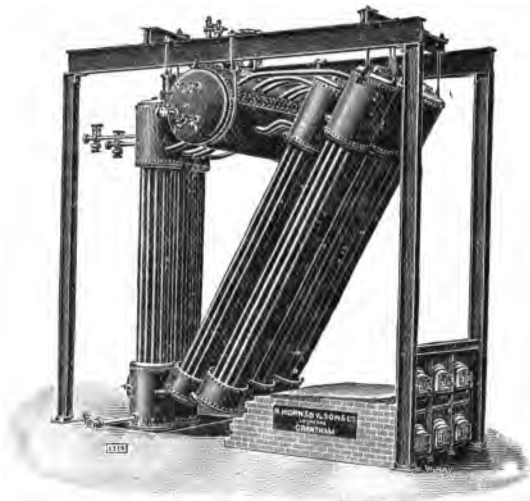
famous firms during recent years, as that of *Water Tube Boilers*, the distinguishing feature of which is that the tubes are filled with water heated externally, whereas those of the ordinary type have their tubes heated internally. As a class, the former has long been deservedly popular for many good reasons, one of the latest examples being the *Upright Water Tube Boiler* by Messrs. Hornsby & Sons, of Grantham, which has been very successfully used for many electric light stations, and mining and industrial operations, etc., at home and abroad.

The great simplicity of this arrangement may be gathered from the opposite illustration, in which, divested of its external brickwork, only the steel framing, the water tubes and drums and their connections, the space for the furnace and the fire doors and ashpit doors, alone are visible. With the enclosing brickwork occupying the space inside the framing, the heated gases from the furnace fill the interior and completely surround the tubes, and also the lower portion of the upper drums, space being left in the latter for the generation of steam which is collected in the large central chamber, from which it is distributed to any desired spot. The view also shows how the evils caused by irregular heat expansion are averted by means of elasticity in construction.

IRON FOUNDRY.

With a sense of relief we passed from the Boiler

Shop to the large and well appointed *Iron Foundry*, which may be termed the "Abode of Silence." The work of the men here employed by day chiefly includes the preparation of moulds for the casting processes of the evening, the floor being covered with loose black sand and plentifully strewed with wooden patterns for



UPRIGHT WATER-TUBE BOILER, WITHOUT THE BRICKWORK.

locomotive and general work. Moulding boxes and foundry appliances of every description also lie about promiscuously. These patterns have been carefully prepared in accordance with the nature and number of the castings to be made from them, hence, to ensure exactness and economy in the case of hundreds, or

perhaps thousands of the same detail, *metal* patterns are used with great advantage.

By night, the scene is one of picturesque grandeur, and as a great quantity of melted metal is used throughout the vast building in filling the moulds, the floor becomes a miniature volcanic region, much too dangerous for visitors in muslin dresses to tread upon.

The timber most generally used for patterns is pine, or deal, and mahogany, the two former being the best suited for large ones, and the last-named for small ones, on account of its closeness of grain and small liability to shrink or twist in drying. To avoid these evils, in any case, the timber should be thoroughly seasoned before being worked upon.

The excellence of a casting primarily depends upon the skill of the drawing office staff, as the pattern maker is entirely guided by the plans prepared in this department. One example out of many will be sufficient to prove this. Some years ago a very eminent firm conceived the idea of making "improvements" in the construction of large steam cylinders, which were of course clearly shown in the drawings. When, however, these cylinders were cast, it was found that some of them were cracked. The plans were therefore altered, and the successes of the past renewed in the future.

Fracture of castings has frequently been caused by improper distribution of metal, and by the introduction of *sharp* corners which ought to have been rounded.

Indeed, the latter not only makes a casting unsightly, and robs it of some of its natural strength, but sometimes creates destructive strains in the metal while cooling in the mould, especially with steel, the fluid temperature of which is higher, and contraction greater, than those of cast iron. Other curious phenomena occasionally appear, such as twisting out of truth, the formation of cavities inside the metal, etc., which have to be guarded against at all points, firstly by the draughtsman, and secondly by the moulders.

As the *weight* of castings has often to be calculated from drawings, with an amount of trouble corresponding to their design, a simple method is sometimes used which gives closely approximate results almost at once, as follows:

Weight of pattern in pine wood when in ordinarily dry condition × 14 for cast iron, 15 for steel, and 16 for brass.

The best material for receiving impressions from the patterns referred to is sand, as liquid metal has no chemical action upon it; it acts as a good conducting medium for the air expelled from the space filled by the fluid; and, lastly, it possesses sufficient adhesiveness when rammed to enable it to retain its form when exposed to the fluid pressure. So important is it, therefore, to have sand of suitable quality that the sites of many foundries have been determined by its presence alone.

All kinds of moulds for heavy castings are prepared

by hand, more or less elaborately, some indeed requiring large pits in the floor, and the expenditure of much time and labour before being ready for the liquid metal. The great majority of small and medium sized ones, however, are made in the usual moulding boxes, with which every foundry is supplied. A rectangular bar, for instance, can be made anywhere by simply pressing the pattern edgeways into the sand and then pouring in the metal. When, however, we come to castings of varied shape, other methods must be used which will enable a perfect impression to be taken of *both* sides of the pattern.

This is accomplished by having two boxes filled with well rammed sand, one of which contains on its face an impression of the lower half of the pattern, and the other the upper portion of the same. When these moulds have been carefully finished they are secured in position, face to face, in such a manner as to produce complete castings when the metal has been poured in and allowed to cool.

In places where an enormous quantity of repetition work of moderate size is made, some more rapid method than that of moulding by hand was found necessary. Hence foundry manager Mr. F. G. Leeder, successfully designed a machine that would turn out a *complete mould at one operation.* Some idea of the usefulness of this invention may be gathered from the fact that 1,000 complete moulds have been made at a small machine in one day by the aid of three boys, and from 400 to 600

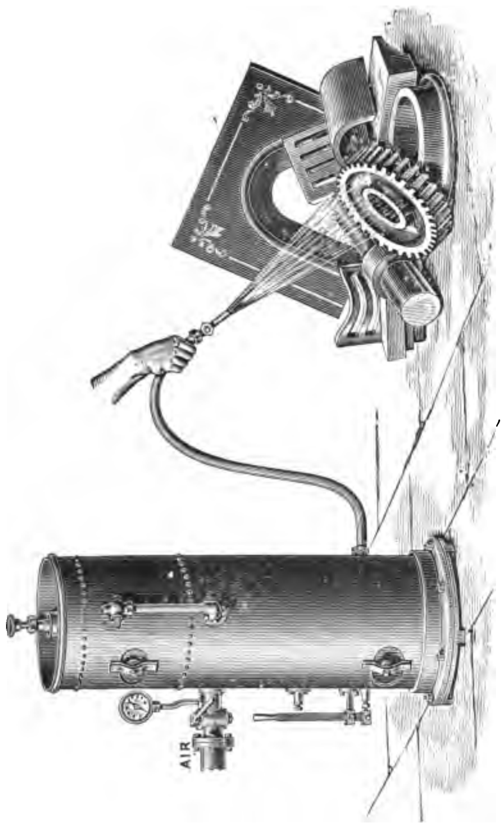
larger ones in the same time by unskilled workmen. In railway works the above process is extensively employed in the production of immense quantities of minor details, thus saving much time.

Formerly, it was the custom to clean castings by hand after having all their rags and tags chipped and filed off. The first-named process is still in use in small places, but at Crewe the *Tilghman Sand Blast*, or "Liquid Grindstone" system, is employed with excellent results. It may be described as a method of cutting, boring, grinding, dressing, pulverising, and engraving stone, metal, glass, wood, and other hard or solid substances, by means of a stream of sand or other suitable material forcibly driven against them by steam or by compressed air. By its aid the hardest steel, etc., irregular surfaces, and recesses almost inaccessible, can be easily operated upon. Hence it comes to pass that worn out files may be re-sharpened in a few moments as they stand, instead of being softened, ground, re-cut by hand, and re-hardened, immense quantities of these being thus treated with great advantage.

The Sand Blast process is now much employed in foundry work, the application of which, for this purpose, may be understood from the illustration on the next page which explains itself, the air employed in this case having a pressure of about ten pounds per square inch. In modified form it is frequently used for painting iron work in inconvenient places.

Before metal of the desired quality can be obtained

for the intended castings, various brands of pig iron have to be mixed in certain proportions previous to



SAND-BLAST APPARATUS IN OPERATION.

being melted. Here, however, we touch the secret arts of the founder, to which no reference need be made. When the above mixture has been decided upon, the

next thing to be done is to melt it in a *Cupola*, suited in capacity to the requirements of the castings which have to be made from it at one time. The pig iron, scrap iron, coke, etc , which unitedly produce the melted metal, are delivered into the interior of the cupola, where, under the influence of a strong blast of hot air, they are soon reduced to the required state ready to be drawn off when needed.

Brass Foundry.

Brass, and also *Bronze*, have been most useful metals from the time of the Brazen Serpent to the present. Coming down the stream of time we find the same materials holding a very exalted position, being used in large quantities for the most important works, such, for instance, as enormous city and temple gates, and statues of all sizes, including the Colossus of Rhodes, which was about 110 feet in height. Hence, we may conclude that, the *Brass Founders'* art was, at an early age, in a very advanced state.

The alloys which, in combination, form the above substance, are chiefly copper, zinc, and tin, the skilful proportioning of which produces a material suited for a variety of purposes. The Bronze alloys are also variously mixed, so mixed sometimes as to produce a metal that, while capable of being forged or rolled, may have a tensile strength of at least 35 tons per square inch. Hence its admirable adaptability to engine and

other work, where great strength, combined with non-corrosive powers, are required.

One of the best examples of this is to be found in the screw propellers of large steamers, which may bend without breaking even under the most severe and irregular treatment; while on the other hand, the immense strength of the metal enables light, thin, and sharp edged blades to be used, thus producing diminished friction and increased speed.

Although the Brass Foundry is of comparatively small dimensions, it nevertheless occupies an indispensable place in the Works, as many minor details, such as bearings, valves, and light fittings generally, must necessarily be made of this expensive metal. There is not much to be said in connection with this department, as previous remarks upon pattern making, moulding, etc., are here quite applicable.

Besides the ingots of fresh metal, a large quantity of waste cuttings from the machine and other shops are well used up. As many of these scraps are collected from the various floors, they must necessarily be extensively mixed with refuse iron and steel, and to enable the brass and copper to be separated from them they are thrown into a large box, containing a revolving spindle having magnets spirally attached to it. These attract the baser metals to them, only to be swept away by revolving brushes, thus leaving the more valuable scraps to be easily gathered for remelting purposes.

CHAPTER VIII.

WOOD-WORKING MACHINERY AT CREWE.

The Manual System of early days—Refined and rapid Modern System—The *Trees* of the Forest lay withered and strown—How accomplished—The Carpenter and his Colleagues in Building—The Joiner and his delicate Occupations—*Saw Mill* and its Arrangement—Practical Notes—Wonderful powers of the modern Band Saw—Improved type for horizontally cutting Heavy Logs—Special Combination Circular Sawing Machines—Wonderful Planing and Moulding Operations—Their greatly diversified nature—Mortising and Tenoning by Machinery on a large scale—Mechanical Sand-papering Process—Emery Wheel grinding of Tools—Proper Tool-cutting Velocities.

We now come to the *Wood-working* regions of the Crewe establishment, where, on a very large scale, carpentry, joinery, and timber cutting of all descriptions are actively carried on. The whole territory, indeed, forms a scene that to some, no doubt, is fascinatingly attractive, owing to the wondrous manner in which timber is manipulated from first to last. Under the guidance of one man at one machine, for example, a rough log is rapidly sawn, planed, drilled, adzed, and finally turned into a finished and interchangeable buffer beam as one stands looking at it, and so on throughout the whole series of operations connected with other details. Here, however, let us pause and reflect upon

this extremely useful branch of practice, and by a few graphic touches help the reader to obtain a general idea of the main processes which are indicated by the term "Wood-working" in in its world-wide significance.

To enable me to gather the desired information as completely as possible, I paid special visits to the extensive establishments of Messrs. T. Robinson & Son, at Rochdale, and also the new works of Messrs. A. Ransome & Co., formerly of London, but now of Newark-on-Trent, so that what I had noted in various places from a *user's* point of view, might be embellished by a few additional remarks from the constructor's standpoint. Here, however, we must retrace our steps.

The greatest event in the early history of carpentry was the erection of Solomon's Temple, which was founded in the year 1012 B.C., and as it was finished only seven years later, we must look behind the scenes for the cause of such rapidity in execution. The ancient records, therefore, inform us that on this occasion Solomon wrote to Hiram, King of Tyre, somewhat as follows:—

> "As I desire to build my house as quickly as possible, please let me have some of your skilled woodcutters to help my own people on Mount Lebanon, and I shall pay you whatever you require."

So pleased was Hiram with this letter that he sent 30,000 hands, and thus the total working staff in the celebrated forest amounted to about 70,000 labourers

and 3,600 "overseers," which will at once account for the unusual speed with which the magnificent edifice was erected.

During the last 100 years, immense improvements have been made in all departments of wood-working machinery; indeed, so extensively have these been utilised during recent times as to be almost beyond belief. From the primitive axe and adze workmanship of the carpenters of two centuries ago, to the refined and perfect machines of the present, has been a gigantic stride; but Watt's steam engine gave, within a very limited period, an impetus to everything of a mechanical nature that has no parallel in the history of the world. The ease and simplicity with which tree-felling, log-sawing, heavy band sawing, and circular sawing machines can now be used, not only upon single trees, but upon *whole forests*, will show how the very slow and laborious manual style of the past has become obsolete, except in places where nothing better can be had. When, too, it is remembered that timber is required in countless forms and on a most extensive scale at home and abroad, it will be noted that for initial process operations these machines are invaluable, as they prepare the way for the carpenter and joiner, whose labours in connection with every kind of building are indispensable.

The former receives his material from the sawyer in beams, planks, etc., which he cuts and combines, sometimes most skilfully, for constructive purposes, such as

gigantic trestle bridges, roofs, timber houses, and so on. The scientific design of these, however, comes within the province of the engineer, whose knowledge of the strength of materials, and also of the numerous machining operations, enables him so to proportion and arrange his details as to obtain the greatest strength at the least cost.

Broadly speaking, the carpenter has for his colleagues the mason, bricklayer, and ironworker, whereas the joiner assimilates himself with the rough furnishers of interiors. Since not only in railway works, but in shipyards and elsewhere, there are many varieties of wood in constant use, including fir, pine, oak, teak, etc., for constructive purposes, and those of a more valuable character for internal embellishments, it naturally follows that this in itself complicates a subject the ramifications of which are intricate and widespread. This is owing to the fact that a machine, when perfectly designed, is made to suit the kind of timber it will most generally operate upon, which may be very soft, as with fir, or very hard, as with oak and other woods. With the object of helping me to illustrate this subject as clearly as possible, the two firms mentioned have kindly supplied me with a list of machines made by them for the Crewe, Wolverton, and Earlestown works of the London and North-Western Railway Company, some of which will be described as we proceed.

Let us suppose that we have entered the *Timber Working Department* at Crewe, that portion of it, at

least, which includes the *Saw Mill* and *Joiners' Shop*. The first thing that strikes one somewhat forcibly is the absence of the overhead shafting and belting usually to be found elsewhere. Here, however, all the motive power gear is placed *below* the floor, where much is to be found in rapid and beautifully smooth motion; engines of 90-horse power and large pulleys and driving belts being used to bring the shafting up to its required velocity. The great advantage of having the latter thus situated, is due to the very high speed which is necessary for various purposes throughout the shop. It is therefore advisable either to drive the main shaft with great rapidity, or to introduce a number of intermediate ones for the same object. The disadvantages of having so many of these with their pulleys and belts overhead are great, and as heavy machinery in that position would throw an undue strain upon the building, it is considered better to place it below the floor, and to fix its supports to piers detached from the walls of the mill.

The engines and boilers should, as a rule, be placed in a separate building, thus giving greater security from fire, and preventing the former from being exposed to the dust and grit so continually flying about. As, however, all the shavings, waste cuttings, etc., are used up for firing purposes, it follows that not only are the shop floors kept clean, but considerable economy results from the very extended use of waste timber instead of coal, which is thus seldom required.

The power of the machines to turn out good work with sufficient rapidity is chiefly due to their cutters being made of the very best steel, their edges having the most approved formation, and their velocity the highest that can be attained. With this in view, the bearings of shafts and spindles running at 4,000 or 5,000 revolutions per minute are made much longer than usual, for good wear, the lubrication being of the most perfect character, and the whole machine so designed, balanced in its working parts, and fixed to the foundation, as to be incapable of vibration. There are other points that require careful attention regarding the arrangement of the buildings and of the various machines, etc., and when these have been properly worked out in detail, a wood-cutting establishment is in condition for executing the most elaborate as well as the most simple work with a speed unparalleled in the mechanical processes.

As the *Saw Mill* produces food for all the other departments, it deserves the first attention. It is here that the enormous logs from the forests of America, Canada, Scandinavia, India, etc., are initially machined by means of vertical frame or other saws which cut them into beams, planks, etc. These are very carefully stocked in the *Drying Shed* until in proper condition for being further operated upon.

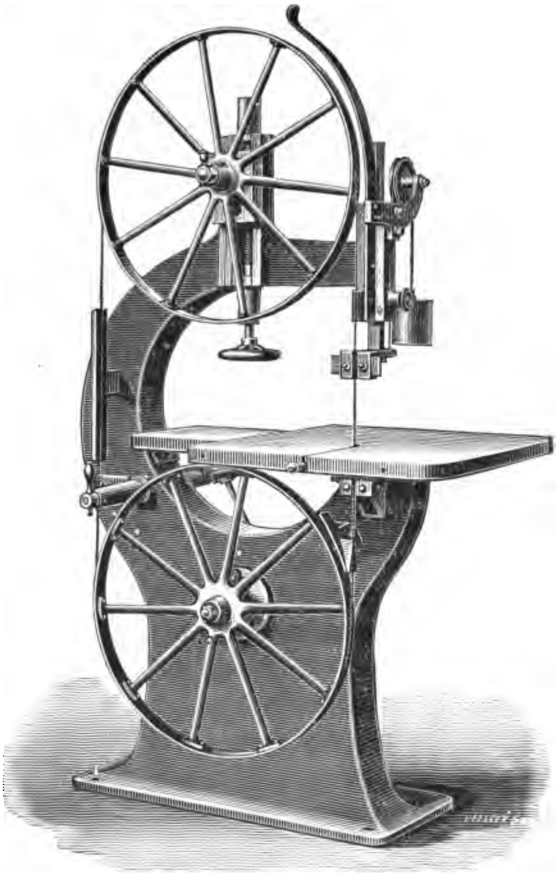
Many will no doubt remember the *Band Saw* of early days, which was only suitable for ornamental carving, it is therefore surprising to find such an enormous

expansion of the uses to which it can now be applied. Who would have thought, thirty years ago, of employing this saw for cutting through massive blocks of iron and steel, as well as heavy timber? And yet such has been the march of progress that all these operations are of continual occurrence in many large establishments.

With a desire to still further extend its sphere of action, numerous firms have designed a great variety of special, and in some cases enormous, machines of this type, for rough log squaring and other purposes. As an example of the manner in which the Band Saw is appreciated in Canada, we may mention that by its aid the daily production of one immense establishment alone has amounted to as much as 1,000,000 feet of timber, cut from 7,000 logs. These logs were first floated down from the forests in rafts to the required spot, and then dragged by an endless chain into the mill to be operated upon.

A good illustration of the above class of machines, by Messrs. George Richards & Co., of Broadheath near Manchester, for ordinary sawing, is shown on next page, the diameter of the wheels being 42″.

This machine owes its excellence to the thin, narrow, and flexible strip of exquisitely tempered steel that forms the saw, which differs from all others, as it has to be united at the ends to enable it to pass continously over pulleys without breaking at the joint. This was primarily the main obstacle, until M. Périn, of Paris, discovered a method of faultlessly brazing



BAND SAWING MACHINE.

the two ends, and thus successfully overcoming the difficulty. For cutting logs up to 5′ 0″ square, or 6′ 0″ diameter, it is more useful than either the large circular saw, or the vertical frame saw, as the waste is much less, and at the same time a smoother cut is produced.

One of the most valuable wood working appliances of the present is the *Horizontal Log Band Sawing Machine*, shown opposite next page, which possesses many striking advantages and points of constructive interest.

This machine is capable of converting round or square logs of any kind of timber up to 36″ diameter and 40′ 0″ in length into beams, planks, etc., whilst effecting at the same time a considerable saving in timber as well as in motive power. The cost of labour in operating is extraordinarily small either when the machine is used for log squaring, or for board cutting and other purposes, the excellence of its output being greatly due to accurate finish of the working parts; to the absolute balance of the saw pulleys; to the rigid fixing of the log upon a perfectly true metal travelling carriage; and to various other causes.

The best known of all the sawing machines is the "Circular," of which there are many varieties, large as well as small. Although very simple, it is nevertheless capable of numerous valuable combinations for the purpose of planing, moulding, tenoning, mortising, boring, etc., to suit the requirements of users.

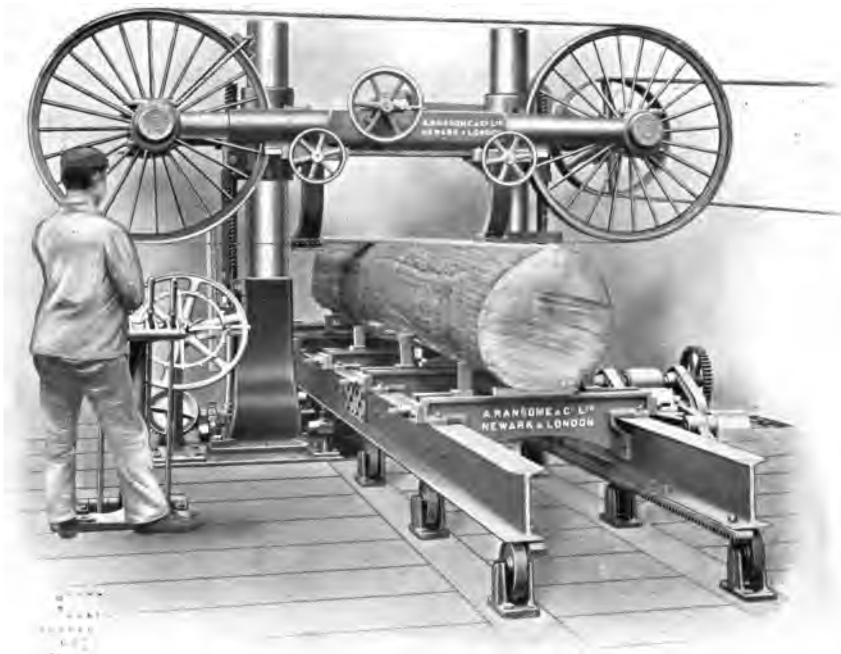
The varieties of the Circular Sawing Machine include, besides the above, those with long travelling

tables for tree cutting — pendulum cross cutters for joiners, etc.—compound machines of various kinds—those with gear feed, rope feed, and hand feed—those of the multiple self-acting cross cut description for shaping pavement blocks by the hundred thousand; and so on, to suit the ever varying circumstances of advanced modern practice.

The action of all the above primary machines is so simple that nothing further need be said about them; when, however, we come to those of the *generally useful* class for planing, moulding, etc., which, to some, may be difficult to understand, a few remarks on this point become necessary. Let us therefore follow the beams, etc., so liberally provided by the sawyers, through the succeeding operations which either transform them into constructive, or into merely ornamental details with marvellous celerity.

Amongst the appliances required for this may be mentioned the *Planing and Moulding Machines*, whose leading principles may be here described.

Suppose then, that we have before us a fir plank $11'' \times 2''$. Let us also imagine that two swiftly revolving horizontal spindles carrying straight cutters, are so placed that the plank, if passed between them, would be just smoothed up on both sides. If, now, two vertical and similar spindles are placed at the sides, so that the timber will be similarly treated on its edges, we shall have an arrangement which, at one traverse of the plank, finishes in flat style the whole of its sides and edges.



HORIZONTAL LOG BAND SAW.

If, however, one or more of these cutters is shaped so as to produce curved, bevelled, or channelled, etc., outlines on the sides or edges, or all together, we then have a combination which, in the most efficient manner, and at one time, performs every operation automatically and with exact interchangeability.

As in all other machines, the greatest care is bestowed upon the construction and fixing of the cutters. These are of infinite variety, the specially shaped holders to which they are attached being so fitted on steel spindles as to allow of their instant disconnection at any time.

In many timber constructions tenon and mortise joints are indispensable on account of their excellent binding properties. In the bush of Australia and other wildernesses they are still cut with the hand-saw and chisel, here, however, something better must be employed, and therefore several varieties of the well-known *Tenoning Machine* are in use for general work, capable of forming either single or double tenons up to 20″ by 8″, with precision and rapidity.

To enable these operations to be performed, the timber is fixed to a table, which runs easily by hand on friction rollers. When thus secured, the end is passed between two swiftly revolving cutter blocks which are capable of vertical motion to suit the thickness of the tenon.

It will no doubt be apparent that tenons cannot be of any use without having mortises to receive them.

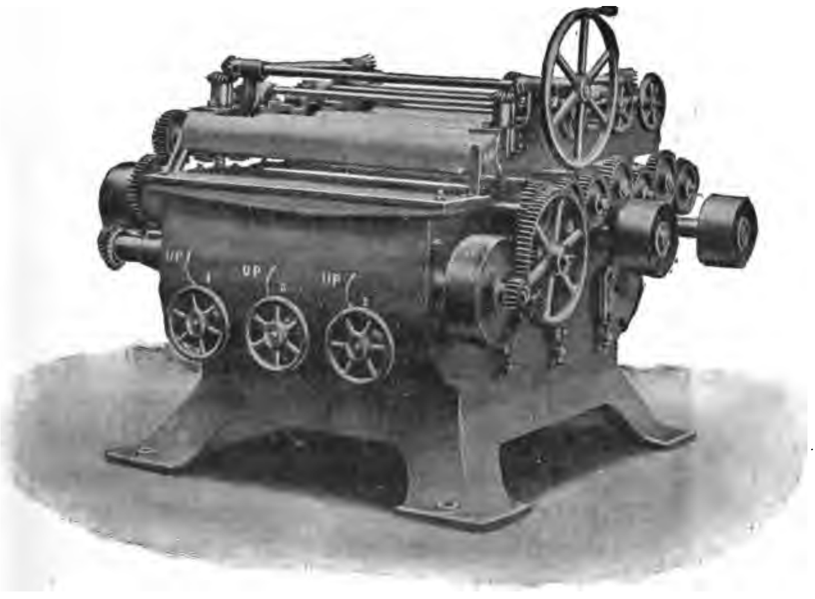
This being so, the manual process can be accomplished by boring holes in the timber, and then chiselling out the rectangular aperture. To avoid this, however, a variety of machines are now fitted with boring and chiselling tools capable of passing through timber of any dimensions up to 12″ square. the maximum breadth of chisel being 2½″. After the first hole has been bored equal to the width of the opening, the chisel is brought into play until the mortise is completed.

For slot, as well as for complete mortising, in either hard or soft wood, horizontal machines are provided with a sawing, grooving, tongueing, and rebating arrangement, which is intended for all kinds of jobbing work. Here the mortising operation is performed by means of suitable boring bits, the timber being clamped to a table, the hand lever of which regulates to a nicety the length of mortise and feed motion at the same time.

Everyone, probably, is acquainted with the old manual sand papering process that was so inherently defective and laborious. An American engineer noting this, invented a machine, which, through the improvements of Messrs. Robinson & Son Ltd., of Rochdale, has attained a high degree of excellence, and proved a valuable labour saver.

The *Invincible Three Cylinder Sand Papering Machine*, illustrated on the next page, to which we refer, has its cylinders so covered with sand-paper of various grades, and so made to slightly oscillate, as to produce with great rapidity work of the highest polish, each cylinder

being adjustable either in motion or at rest. The paper is fastened to the revolving cylinders in the simplest manner, and to prevent any clogging of the surfaces through accumulated dust and grit, an exhaust fan is supplied to carry the latter away. As the



THREE CYLINDER SAND-PAPERING MACHINE.

machine is made in five sizes, capable of operating upon timber from 24″ by 4″, to 60″ by 4″, its great usefulness in establishments where polished work is produced in immense quantities will be evident.

In these few remarks upon *Wood-working Machinery,*

we have only referred to some of the principal appliances of this nature at Crewe, Earlestown, and Wolverton. It may be well to note, however, that with all their cutting tools, it is absolutely necessary to have the best means of accurately dressing and sharpening them when worn, as the old methods of doing so have long since been found very defective.

For short cutters, an ordinary grindstone, with *Emery Disc* attached for fine edge finishing, does well, but for moulding cutters of all kinds a *Multiple Grinding Machine* becomes indispensable. For long and straight-planing cutters, however, *Self-acting Emery Grinding Machines* are necessary.

A very useful Crewe appliance for dressing vertical, horizontal, and circular saws, is a *Saw-sharpening Machine*, in which the two first named are held by a vice, whilst an emery disc does all that is required, circular saws being fixed on a vertically adjustable spindle to suit various diameters.

As proper *tocl-cutting velocities* are of immense importance, it may here be said that, according to the latest practice of Messrs. Robinson, *Circular Saws* should, as a general rule, be run at a circumferential speed of 9,000 to 10,000 feet per minute.

Band Saws should travel at the rate of about 5,000 feet for ordinary work, but in specially constructed machines this may be advantageously increased to 7,000 feet.

Rotary Cutters for planing and moulding should simi-

larly have a speed of 5,000 to 7,000 feet on their periphery, and *Emery Discs* a circumferential velocity of 4,000 to 6,000 feet per minute. With these data in view, it is not difficult to ascertain the speed of spindles and shafts, and also the wheel and pulley gearing necessary to produce such results, which, indeed, form the basis of all calculations for machinery of every possible description, either for wood or for iron-working, no matter what its motive power may be.

CHAPTER IX.

SPECIAL ENGINEERING DEPARTMENTS AT CREWE.

Millwright's Shop—Its various Occupations—*Smithy* and its Contents—Special advantages of Electric Welding—*Erecting* and *Repairing Shops*—Their immense extent—300 Engines in hand at one time—Diversified Dilapidations—*Painting Shop*—Distinguishing Colours of Locomotives—*Wheel Shop*—Its heavy Machines, etc —Rapid Crank Axle turning Process—Special Axle Box Machine—Planing Machines—Their Prodigious Scope—Lathes in the Railway World—Their Wondrous Diversity and Unique Value—A valuable Time-Saving Improvement—*Spring Shop*—Special treatment of Springs—*Signal Fitting Shop*—How the Safety of the Public is insured—*The Great Machine Shop*—Striking impression on Visitors—Engine Detail boiling Process—Drilling and Boring Machines—Their Wide Range of Usefulness.

LEAVING the timber-cutting departments of the Crewe Works behind us, let us now proceed to the other spheres of interest and activity which are so abundantly to be found in this unique establishment. In the *Millwright's Shop*, which comes next in order, we find a great variety of work in progress. This includes steam and pumping, etc., engines of various kinds, warehouse appliances, light and heavy lifting gear, crank shafts and other work for the Company's numerous steamers, electrical, hydraulic, and all other kinds of machines for

general purposes throughout the whole of the railway system, which are either in course of construction or undergoing repair. It may be observed that, while in the purely locomotive departments, there must necessarily be a great amount of repetition employment, here there is sufficient variety to deeply interest ambitious students, and enable them to understand more clearly the inner secrets of railway practice. The constructive machinery, however, in this region, hardly requires comment, as it is so well known.

We next enter the *Chain Making and Testing Shop*, where every description of chain is made, and where samples of steel from boiler plates, etc., and other materials are subjected to the most severe treatment to prevent the possibility of accidents through hidden flaws or imperfect manufacture.

Passing onwards, we reach the *Smithy*, with its 120 blower-blasted hearths, where all the smaller parts of the engines, etc., are forged large enough to allow for their machining to the exact dimensions. This, indeed, is a centre of life and energy, in which numerous steam hammers are constantly employed. As each fire is worked by a smith and his attendant hammer man, it may readily be supposed that the ringing of the anvils under repeated blows, and the sparks which fly around, have a very fine and picturesque effect, which to visitors is best viewed at a safe distance. Welds in this shop are usually made under the steam or the sledge hammer; an *Electrtc Welding Machine*, however, is

additionally employed, by means of which pieces of metal are united by fusion, the required heat being generated at the points of contact by an electric current. Hence, welds that cannot otherwise be produced without a disconnection of parts, may thus be rapidly and perfectly formed.

Leaving the *Erecting Shop*, with its crowd of *new* locomotives in course of construction, out of sight, we find ourselves in the vast *Repairing Shop*, 993′ 0″ in length, by 106′ 0″ in breadth, where at least 300 engines may be operated upon, and in some cases practically rebuilt, at one time. The scene is impressive, owing to the extremely varied states of disorder of so many of them, fully 2,000 being here repaired annually, and, in many cases, made to look eventually quite new after all the wear and tear of their past lives. Here may be found the representatives of 14 different classes of locomotives, from those of the magnificent Compound Flyer to the commonest shunter, one of the former, now before us, being in a state of demi-semi-wreck, through serious derailment. Others, again, are in a state of chaos, with boilers gone, framings dishevelled, wheels missing, and with the general working gear more or less disarranged.

The whole place looks like a vast mechanical hospital, where dislocated, distorted, broken, bent, and twisted members are lying upon the floor around us in a state of greasy dirt, ready to be sent, after cleaning, to the machine and fitting shops for rectification and

renewal. The shop itself is a splendid specimen of ingenious design, as all necessary labour-saving machines and appliances are at hand. Overhead cranes are also sufficiently numerous to sweep the whole area, and carry engines bodily and swiftly through the air to any desired spot.

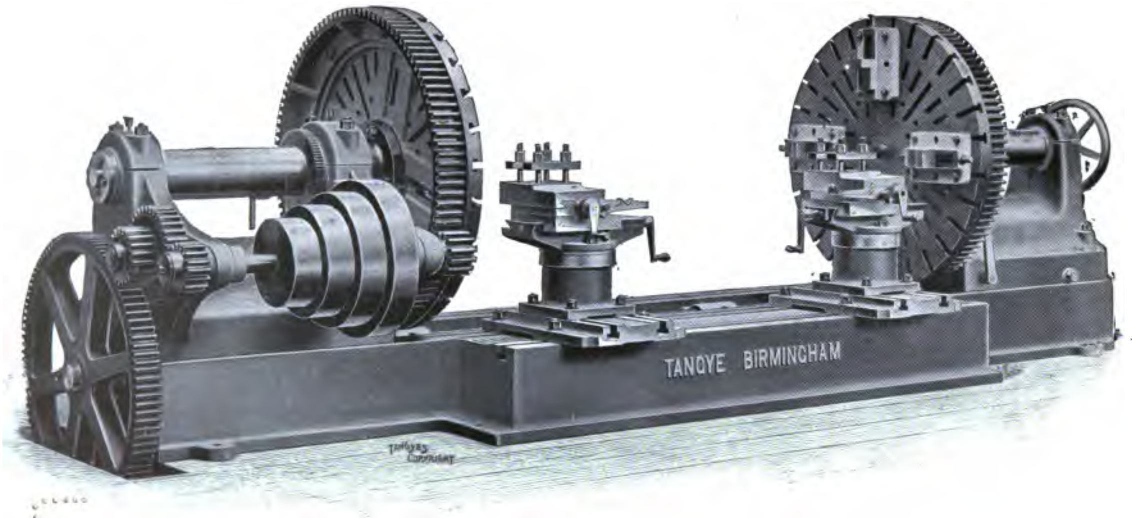
When the repairs have been effected, the engines are taken to the *Painting Shop*, where, after the application of the required number of coats of paint and varnish, and superfine polishing, they are ready to reappear in public, and continue their arduous labours. As a steamship owner employs a certain colour of funnel to enable his vessels to be recognised at a distance, so also do Railway Companies adopt special foundation colours for their locomotives, which may be green, or blue, or reddish brown as on the Midland, or any others as distinguishing marks. For this reason the London and North-Western prefer *black*, which, with a little relief touching up and fine finish, gives a better and more substantial appearance to a mechanical structure than one would suppose, and is preferable to light blue or emerald green, which are not æsthetically suitable for machinery.

As the repairing and new erecting departments are extensively supplied with much of their heavy gear by the *Wheel Shop*, let us now take a turn through this part of the premises, whose name indicates the nature of the operations chiefly conducted in it. This soon becomes apparent as numerous *Wheel Lathes* rise to view, and also an extensive assemblage of wheels from 7′ 6″

drivers, down to 3′ 6″ leaders and trailers, etc., that have either been turned or are waiting to be operated upon. The usual plan is to have rows of the above lathes down one or both sides of the shop, axle lathes and other heavy machines being placed where most convenient. To aid all these most efficiently, a line of rails traverses the centre of the building, so that wheels may be run in to any of the machines. The Plate opposite gives a good idea of the general appearance of this class of machine, which holds a greatly valued position in the railway world, and which, in connection with many others of varied nature shown throughout this volume, will incidentally illustrate a most important phase of *Life as an Engineer* not yet touched upon. This refers to that magnificent class of *Constructive Machinery* which, in the hands of many inventors, in later times, has produced marvellous economy in the cost of production in every branch of engineering. For this reason, especially, these illustrations deserve close study apart altogether from their direct connection with the text.

The machine referred to is usually designed for operating upon engine and tender wheels from 3′ 6″ to 8′ 0″ diameter, that illustrated being of the 4′ 0″ size. For the turning, etc., of wagon and carriage wheels, in immense numbers, comparatively inexpensive lathes of a similar class are very usefully employed.

The *Crank Axle Lathes* at Crewe are specially designed for dealing economically and accurately with the heaviest class of work. At the front of each of



RAILWAY WHEEL LATHE, FOR WHEELS UP TO 48 INCHES DIAMETER ON TREAD.

these machines, as well as at the back, there are several slide rests for sliding purposes, and also for cutting the outsides of the webs of the cranks, the whole of the tools being available at one time. After a powerful nibbling machine has roughed the pins out of the solid metal, the lathe finishes them to perfection.

By means of a special planing machine, whose cutting tool is radially fed, the U shaped insides of a number of axle boxes are finished at one setting, whole rows of them having their exterior surfaces trued up in an ordinary *Planing Machine* somewhat similar to one shown in the adjacent plate. This machine will plane a width of 48″ by 12′ 0″ in length, and may also be considered a good representative of a class which, in various forms and sizes, is now very generally employed, from those whose cutting area is 2 feet in length, by one foot in width and height, to at least 30 feet by 12 feet. Amongst the latter may be classed those for armour plate planing, whose power is sufficient to make four tools simultaneously take cuts in steel 1½″ deep by ¼″ in thickness.

The other branches of the Planer family include Portable machines, Shaping machines, Boiler Plate Planing, etc., all of which are among the *foundation* machines upon which the whole fabric of modern mechanical engineering may be said to rest.

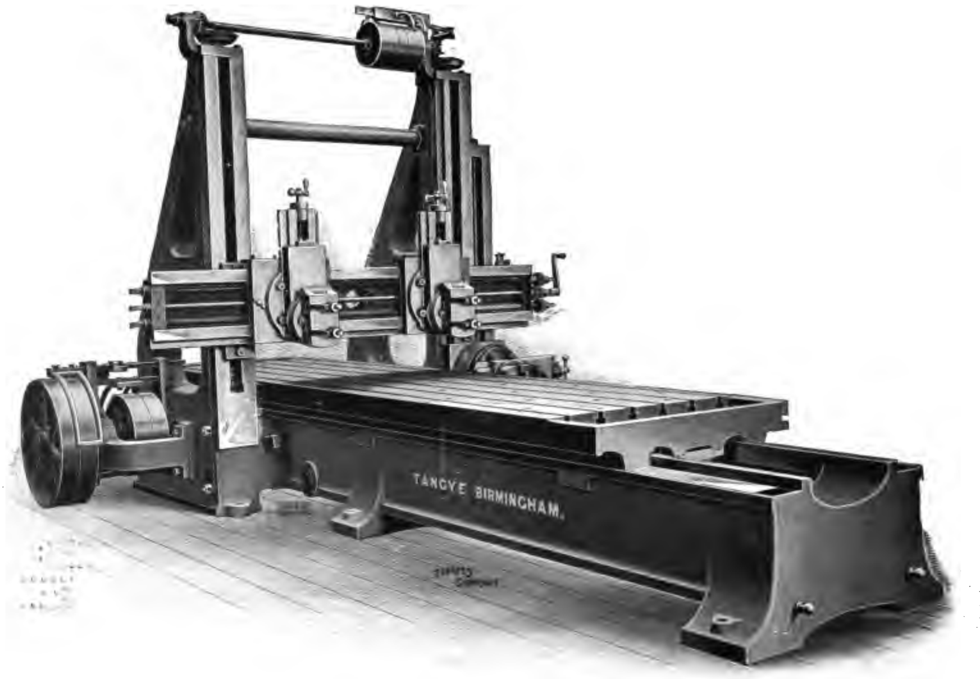
As it happens that at Crewe enormous quantities of rail switches and crossing points have to be specially treated, some more than ordinarily rapid and exact

method must be used. Hence, we find that for this purpose ordinary planers are fitted with double tables—one over the other—the upper of which is hinged at the back end, and made capable of angular adjustment at the other end, thus ensuring complete interchangeability with the least amount of trouble, while at the same time a number of rails, placed side by side, may be simultaneously operated upon.

As in railway work generally, enormous quantities of straight axles are used for engines, tenders, carriages, and wagons, the *Double Axle Lathe* was invented so that each end of the above could be turned at one time. The Plate on next page of one of these improved machines shows very clearly their general arrangement, the fast headstock not only containing in itself the driving power, but, when fitted with face-plates and centres which can be bolted to its hollow spindle, may be used for ordinary turning, and also for facing purposes. As one of the loose headstocks is capable of transverse motion, axles can be easily put in or taken out of this machine.

As the Crewe establishment executes large quantities of general work, it necessarily requires more or less powerful ordinary lathes to carry on the various operations, we therefore show in the Plate opposite page 132 a *Sliding, Surfacing, and Screw-cutting Gap Lathe*, which will help to indicate the arrangement of others as a class.

This machine is fitted with a guide screw for screw



PLANING MACHINE.

cutting, a rack for quick hand traverse, and a shaft at the back so worked as to produce different rates of feed for sliding and surfacing purposes. Although in other machines duplex, and even double duplex compound slide rests are employed for special work of a repetition nature, one only in this case is considered necessary. To prevent long and small shafts or rods from springing under the action of the tool, an adjustable stay is attached to the saddle, which, however can be removed at any time. The swing frame and train of wheels for screw cutting are clearly shown. These wheels range from 15 to 120 teeth, advancing by 5 teeth for each, and may be used in various combinations for mere sliding, if necessary, or for screw cutting. The *gap*, as shown in the view, is covered with a portable piece of the main slide, but this can be removed when any object of large diameter has to be faced, for which a large face-plate becomes necessary.

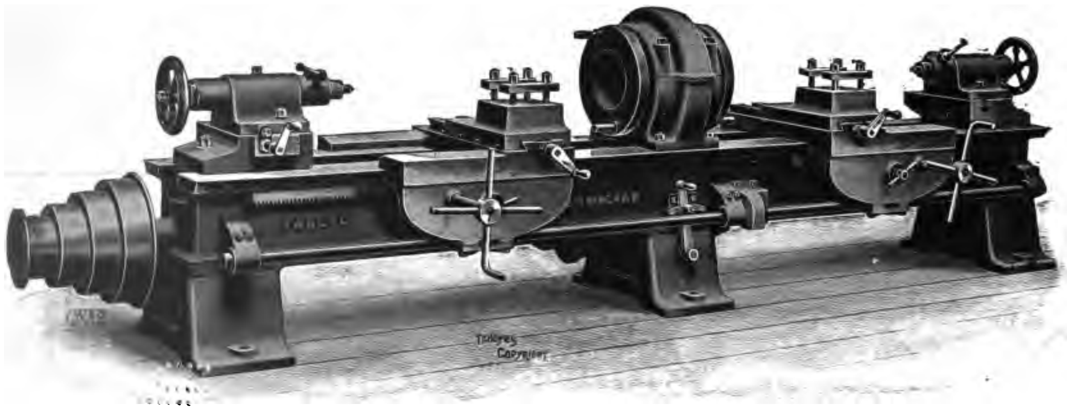
The monarch of all the machines is the *Lathe*, as it is able to drill, bore, surface, and cut screws, in addition to its own particular work, which no other machine can accomplish. The *continuous* action of its tools, and the unique simplicity of its performances are invaluable advantages. The varieties and applications of the lathe are almost beyond belief, except to the initiated, as it ranges in size from the small foot-driven specimens up to those of truly colossal dimensions for great gun, and crank-shaft turning for the most gigantic ships in existence.

One of its most valuable improvements during recent years is the *Patent Automatic Variable Speed* driving arrangement of Messrs. John Lang & Sons, of Johnstone, near Glasgow, by means of which the tool cutting velocity is kept steady while surfacing a constantly varying diameter, such as a cylinder cover, thus saving much time when compared with the old system.

The unique value of the lathe may be still further gathered from the fact that without its aid mechanical engineering could hardly have existed, and if this had been the case we should, even now, be no farther advanced in practical science, or in travelling or manufacturing resources, than the ancients. Hence, we may well hold in supreme estimation a machine which monarchises all others, and is productive of the greatest benefits to the world at large.

The *Spring Shop* which now rises to view as we move onwards, is in every way capable of dealing with enormous quantities and varied descriptions of work. Here men are employed in bending and tempering steel plates, and building them up into springs, which are to be securely fastened in the centre with suitable hoops or buckles. Owing to the peculiar shapes of these buckles, it was formerly very difficult to separate them for repair purposes, hence hydraulic power came to be used, by means of which the springs and their hoops are easily and rapidly disconnected.

The importance of having all the rolling stock springs carefully made, tested, and adjusted when in



RAILWAY AXLE TURNING LATHE. HEIGHT OF CENTRES, 11 INCHES.

position, may be understood when it is known that the smooth running, and, indeed, the safety of the carriages depends very much upon them. To ensure the necessary perfection of material, workmanship and design, every spring is tested in a hydraulic machine to a pressure of so many tons, with as much apparent ease, too, as if it had been of indiarubber. Finally, to enable the drawing office authorities to know exactly the *experimental* strength of all kinds of springs, full records are kept for this purpose.

The *Signal Fitting Shop* is a very interesting portion of the works, which greatly overrules the safety of the whole railway system. This shop is 280 feet in length by 85 feet in width, the machinery contained in it being driven by a gas engine of 48 horse power. There is plenty of *steam* power to be had adjacently, but as this department is often busy when the others are at rest, the gas engine is found very convenient.

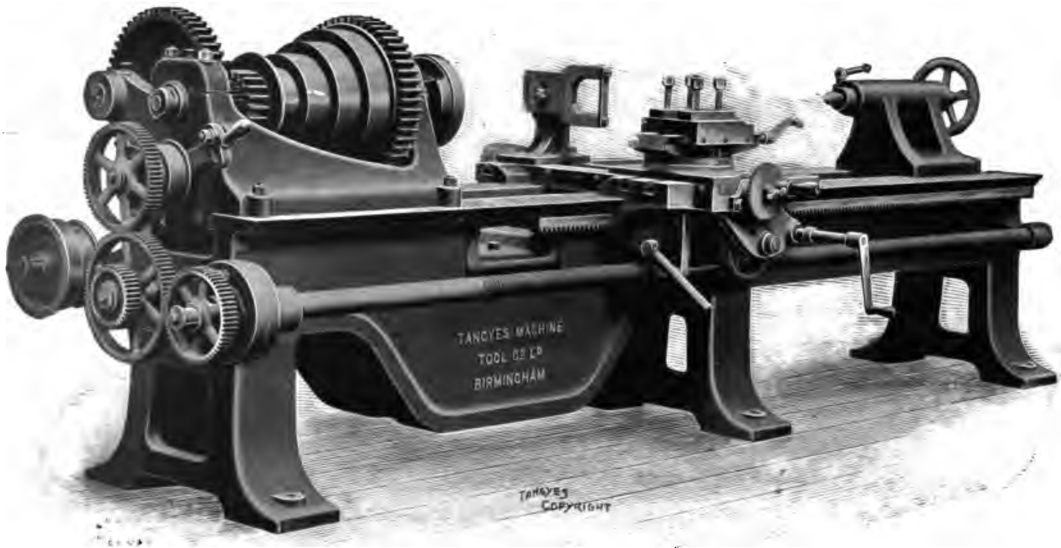
One side of the shop is devoted to the preparation of signal posts, which are received from the sawmill ready for fitting. These posts vary in size from 9″ to 15″ square at the bottom end, and tapering to 6″ square at the top, the length varying according to circumstances. The whole shop, however, is fully occupied in executing all the delicate operations that enable complete sets of signalling apparatus, with their surrounding gear, to be built together ready for fixing in position on the line.

Amongst many beneficial alterations connected with this department may be mentioned the improvements

which have been made in the long rods for working the signals, etc., to be seen at any station. When formerly made of ordinary wrought iron gas pipes, screw-jointed in long lengths to each other, they were often weakened by internal corrosion that could not easily be detected. Square steel rods of channel section are therefore used instead, with the *hollow* side downwards, partly for strength and partly to avoid being receptacles for water. These rods are rolled at Crewe to a standard section in large quantities; then sawn to 18′ 0″ lengths, drilled in a multiple machine, fish-plated to each other, and after receiving one coat of red lead and another of red oxide paint, will last a long time uninjured by the weather.

It is not too much to say that without a proper signal system, and signals that are kept in perfect working order under all circumstances, much of the skill bestowed on the line and rolling stock would be neutralised, as some of the most dreadful accidents of the past have abundantly proved. To avoid these dangers, the greatest vigilance is exercised over the vast and complicated array of "home," "distant," "junction," "platform starting," "advanced starting," etc., signals and interlocking apparatus that guide the working of the various lines, so that not a single point rod or signal arm can fail to answer the action of the operator.

To ensure all this, the whole of the London and North-Western Railway system is divided into numerous districts, each of which is in charge of an inspector. These officers are assisted by sub-inspectors, foremen



SLIDING, SURFACING, AND SCREW-CUTTING GAP LATHE.
HEIGHT OF CENTRES, 10 INCHES.

and others. The above districts are subdivided into lengths, each of which is under the care of a chargeman and an assistant, who visit every signal cabin on their station once a fortnight, clean and oil the fittings of each signal and point, execute small repairs or renewals which it is possible to carry out during their visit, and report to the inspector of the district any which they may find necessary, but which they themselves are unable to deal with on the spot. Heavy repairs and renewals are executed by an extra gang attached to each district, in charge of a responsible foreman, the most stringent rules being laid down as to the manner in which the work is to be carried out, so as to provide for the safe and uninterrupted conduct of the traffic during the time it is going on.

With the object of maintaining the *Permanent Way* and *Works* in the most complete order, a similar but much more extensive system of organisation has been found necessary, a small army of men being employed for this purpose. So thoroughly are the various lines thus supervised that not even a lineal yard of rail, with its fish plates, chairs, sleepers, etc., escapes the lynx-eyed vigilance of those who, unknown to the public, continuously watch over their safety, from day to day, and at once rectify any fault that may appear. As the above "works" include bridges, tunnels, cuttings, embankments, viaducts, stations, etc., and all kinds of buildings, it will be seen that the safe maintenance of a great line is a highly responsible and most comprehen-

sive undertaking, and one which involves the constant application of some of the highest branches of practical science, which, it may be added, enter very extensively into the daily life of the railway engineer.

THE GREAT MACHINE SHOP.

A walk, even in the most casual manner, through this portion of the Crewe Works, accentuates all that we have previously remarked regarding the value of special labour-saving machinery where there is much of a repetition nature to be done. To non-professionals, as well as to engineers, a visit to this vast shop must be profoundly interesting, especially when compared with the less refined parts of the establishment, which, however, to the experienced, convey much more than many would suppose.

The first thing that strikes one upon entering the former is the forest of belts, drums, pulleys, countershafts, etc., with all their accessories, that transmit varying velocities to the machines, quite independent of their own wheel gearing, which further produces similar results. In gigantic shops, generally, the ground floor machines are frequently of colossal dimensions, and with plenty of space around them to allow for the transport and manipulation of heavy castings and forgings. At Crewe, however, the department we are now surveying, extensive as it certainly is, would be much greater were it not that an enormous number of the previously noted large and medium sized machines had been placed in

other parts of the works for convenience. It therefore happens that the magnificent array of beautiful mechanisms now before us is employed chiefly in the finishing processes connected with large quantities of locomotive, tender, and other details of very varied character, though of lesser dimensions than are, as a rule, to be found elsewhere.

A glance in an all-round direction reveals the nature of the operations here carried out. To the right, a number of cylinders are being bored to a dead true surface, whilst others are having the ports slotted and valve faces planed. A lot of axle boxes are undergoing exterior planing on one machine, and a number of slide valves on another. Coupling rods are being milled all round in faultless fashion. Connecting rods are being drilled, milled, and planed to absolute perfection. Piston rods, valve rods, and all kinds of cylindrical gear are in the hands of numerous turners, whose lathes are rapidly reducing them from rough forgings to finished work. There is also to be seen, lying about on the floor, an extensive assortment of gear for inside and outside work throughout the whole of the London and North-Western Railway system, which has to be erected in a new structure or replaced in position in an old one.

I am pleased here to note a most important fact connected with all *repair* work at Crewe. Details that have been taken out of engines for amendment are usually in an abominable state of black greasy dirt, which, in places not so fully organised, has to be

removed by hand as far as possible, thus causing loss of time and very disagreeable employment to those who may be put "on the job."

With the object of rectifying this evil, boiling pans are used for economically and effectually removing the oil and grease from every part after disconnection, the grease being collected and manufactured into soap. From this it will be seen how an apparently insignificant operation can be turned into a source of revenue, not to mention the subsidiary advantages named. Truly, the Crewe establishment is a wonderful place from beginning to end! This, however, is not surprising when the vastness of the undertaking is considered, and also its highly talented Chief Mechanical Engineers, who have in their own way introduced important changes which in other works have been more or less overlooked.

"If you can get your engine to run *twelve* miles an hour," said a Parliamentary Commissioner to George Stephenson, previous to the famous locomotive trial at Rainhill, near Liverpool, "I shall eat a piece of a stewed engine wheel for breakfast." Here, kind reader, we *boil* 'em, which makes all the difference.

As we gaze around, we observe many of our old and time-honoured machine friends of, in some cases, fifty years' improvement, and in sometimes double, treble, and quadruple arrangements.

The original hand drill has become developed by successive inventors into a powerful drilling machine.

This, again, has been promoted to the ranks of the very important family of *Borers*, which begins at the driller of say 3″ hole capacity, and ends at the colossal machines for boring cylinders up to 120″ diameter, all sorts of which, for every conceivable purpose, being now constantly employed.

One of the most useful of recent type *Boring and Facing Machines* for general as well as for special work, is that shown on page 141, which possesses several excellent features. The lower table is longitudinally, and the upper one transversely traversable for distances of 34″ and 36″ respectively, while at the same time the boring head has an 11″ vertical motion for adjustment. This head is capable of edge turning and facing circular objects up to 22″ diameter.

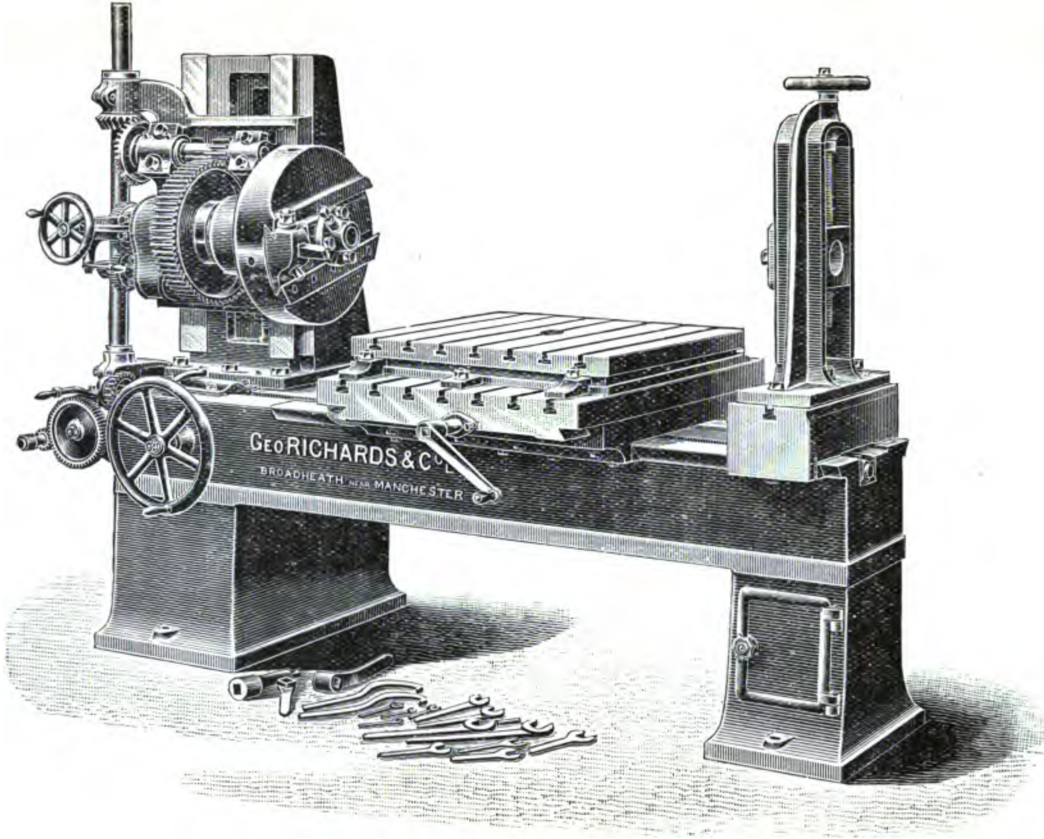
By placing a *revolving table* on the top of the upper one, its utility at once becomes greatly enhanced, as angled, bent, and irregularly shaped pipes, etc., can at one setting, have their flanges turned and faced in any position with the greatest accuracy.

By the addition of a *slide rest*, and by the substitution of a bolt-holed face-plate instead of the cutter disc now on the spindle, wheels and pulleys can be bored and turned as in the lathe. If pump or small cylinder boring is required, all that has to be done is to place a solid boring bar in the machine, the outer end of which is carried by the vertically adjustable stay bracket bearing. The comprehensive nature of this machine thus coming fully into view.

The ordinary *Drilling Machine*, in variously improved forms, now permeates the whole domain of Engineering. Its powers are not merely confined to the formation of bolt, pin, and rivet holes, but also in cutting apertures of all kinds in plates, upon the perforated postage stamp principle, after which the piece to be removed can easily be taken out. The burglar knows this elementary truth when he tries to rob your treasure-laden safe, only, however, to find himself baffled by steel plates so hard that even his own special drills cannot touch them.

A very useful specimen of a *Radial Drilling Machine*, by Messrs. Tangye, is shown in the Plate opposite page 142. This machine has been specially designed for quick and convenient handling at all points and for all purposes, including drilling, or boring, or screwing holes in large castings, etc., placed on its lower table. The 72″ radial arm swings through an arc of 190°, and can be locked in position for heavy work, when required, besides having a rising and falling motion.

The great value of the Boring Machine is due to the fact that, without its aid, the steam engine must ever have remained in its original barbarously unworkable state, with its cylinders and pistons *rough cast* and *holy-stoned*, and packed with rope, squeezed steamtight? by means of the "junk ring," instead of having the exquisitely beautiful working properties which this machine alone can render possible, and with an amount of success which has immensely benefited the whole world.



HORIZONTAL BORING AND FACING MACHINE.

CHAPTER X.

STUDIES IN THE GREAT MACHINE SHOP—*continued.*

How they influence Engineers—A Master Stroke Invention—Its wide spread Effects—Its Modifications—Importance of "Little Things"—How Bolts and Rivets are made in millions—How Labour-saving Machines affect Workmen—Advantages of reducing Cost of Production—Screws and their History—How made to day—Hollow Spindle Turret Lathe—Its Wonderful Performances—Slotting Machine and its Modern Applications—Milling Machine—Its recent Improvements—How one good Invention assists another—Marvellous Range of the Miller's Powers—Its Effects upon the Watchmaking and Sewing Machine Industries—Also those of the heaviest Engineering productions—Final Remarks upon the Crewe Works—The Border Land of Science—Side Lights upon Life as an Engineer.

In continuation of the remarks in the last chapter upon the Constructive Machinery of the Crewe Works, a few practical notes may be given upon a branch of Engineering which not only closely affects the establishment just named, but all others in greatly diversified forms. Let me, therefore, kindly observe, that as it enters very closely indeed into the daily life of most engineers, especially those who in their designing practice have to study economy in production, as well as excellence in execution, it is very necessary that a little more attention should be bestowed upon this subject ere we pass to other themes.

RADIAL DRILLING MACHINE. RADIUS, 72 INCHES.

While, on the one hand, the lathe and drill are of very ancient origin, the planing machine only dates back to the year 1825, when it was invented by Clement, of London, with the object of reducing the manual labour of chipping and filing truly flat surfaces. This invention was a masterstroke of design, as it opened out numerous immense improvements in early engineering practice, the most important of which was the *Slide Rest* for the lathe, which, by the aid of Mr. Whitworth, completely revolutionised the whole system of tool working in metal, as it abolished the prehistoric methods of turning by hand tools which previously existed.

A highly advanced type of the usual planing machine has already been illustrated, there are, however, many modifications of this to which reference might be made if space permitted.

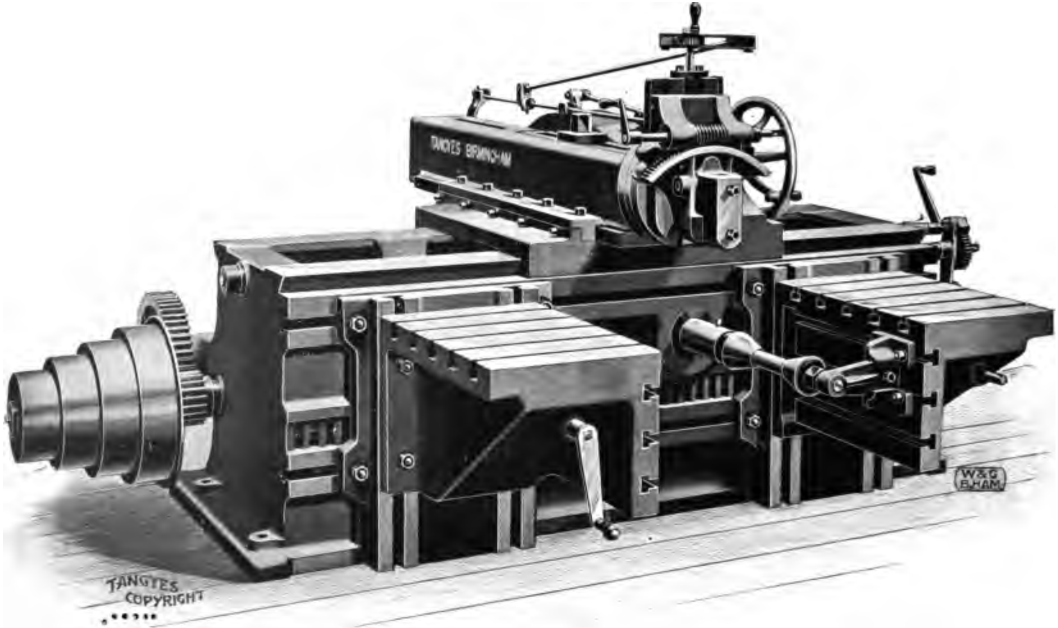
In all Engineering establishments there is a large amount of small and medium sized work that is of too variable a nature to be economically executed by planers and slotters. This led to the introduction of the *Shaping Machine*, which combines the actions of both in a very satisfactory manner, especially where details are of a complicated, or almost circular, or otherwise irregular form. These machines may be either of the single-headed type, as shown in the Plate opposite next page, or of the duplex class.

In all cases there is a quick return motion of the rams, which are capable of adjustment in every way to

suit work on any part of the tables. These latter are adjustable along the bed, and also vertically by means of screws worked by the handles in front. For small gear, otherwise difficult to secure in position, parallel vices bolted to the tables, and capable of swivelling, come in most usefully, and when the mandrel between the latter has its reversed cones for instantaneous setting pressed against each side of the eye of a lever, its boss can be automatically finished with little trouble. The ram has variable strokes up to 24″, its tool box having a vertical slide capable of swivelling for angular cuts, whilst the box itself can be radially traversed by a worm segment for the purpose of shaping internal curves.

Nothing, perhaps, shows the immense importance of studying the properties of *little* things in engineering practice than the numerous appalling accidents which have happened through carelessness regarding some apparently insignificant detail, such, for example, as a bolt, or pin, or rod, which has vital work to perform. So extremely simple, and so universally effective is the first named, in construction and application, that, without its aid, the whole fabric of mechanical engineering throughout the globe would fall to pieces.

This little detail is either forged, when of large diameter, and turned in the lathe to the exact size, or directly machined out of a sufficiently large solid rod and similarly fitted to the place intended for it. For the millions of ordinary bolts, however, for common work,



HEAVY CUTTING SHAPING MACHINE—24 INCH STROKE.

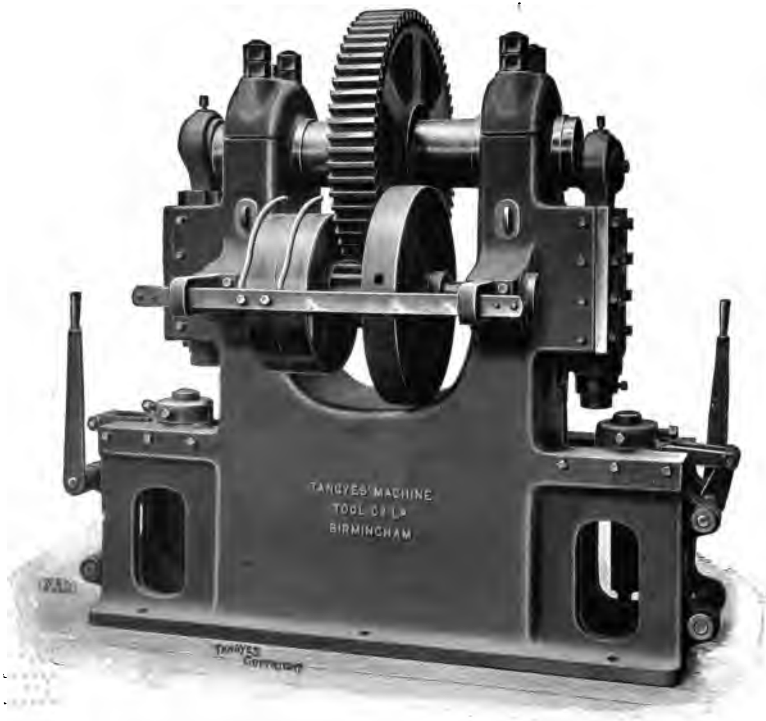
such as pipe flange fastenings, etc., a much cheaper system is necessary, and hence we have machines which, with unskilled labour, can turn out prodigious quantities with great rapidity, one of which, specially arranged for making bolts, spikes and rivets up to 1″ diameter and 18″ in length, is shown in the next Plate. The pieces of rod, after being cut to the required length and heated, are placed in the holders and moved by hand-levers under the reciprocating die heads. These, by compression, form the head of the bolt, etc., which is then automatically raised to enable it to be removed, thus producing continuously solid work instead of, under the old system of forging, an occasional bad *weld* of head to shank. The process just described illustrates to some extent that of stamping by percussive force, which, by means of variously shaped dies, enables sometimes intricate forgings to be made with great ease, thus saving much labour and fuel.

Workmen have, all along, greatly objected to innovations such as these, which interfered with hand labour. This, at first sight, seems only reasonable, but it must be remembered that the introduction of high-class machinery has so cheapened the cost of production as to provide immensely increased employment, owing to the universal extension of manufactures which were formerly confined to very small limits. It may be added that, in view of the increasingly severe competition of foreign countries for the trade we once so extensively possessed, it is absolutely necessary to keep

down working expenses to the utmost, and thus retain employment for the multitudes who otherwise might seldom have any. This is just what the splendid machines already described, and others to follow, are so effectively accomplishing in *their* own way. Hence working engineers should be very pleased indeed to have such valuable mechanical assistants to lighten their arduous labours and to benefit them financially, as most men will certainly allow when, without prejudice, they fairly study the case in all its bearings.

There is no method of fixing the parts of machinery together that is so simple, so efficient, or so easily adaptable to the different phases of engineering practice as that of the bolt and nut. Of course, we fully recognise the indispensability of the gib and cottar, or the latter alone in many cases, but for all round suitability on a world-wide scale, there is nothing to equal the first named attachment, which has a history quite its own.

In early times the threads of screws were irregularly made, according to the ideas of the designers. This, however, caused such great and wide-spread inconvenience, that Mr. Whitworth found it necessary to experiment with a large number of screws, so that he might ascertain their best form and relative number of threads per inch. When this was done, he made them of all diameters to fit a standard set of gauges of his own manufacture. Thus it came to pass that a "one inch," or any other nut made in England, accurately



BOLT FORGING MACHINE.

fitted a bolt of the same diameter from Bombay, or Melbourne, etc., to the very great advantage of the world at large.

It is almost beyond belief the enormous amount of *Screw cutting* of a minor character which has to be performed by special machinery. Long ago, a great deal of the former was made in slow working machines, until advanced science enabled a much larger quantity of better work to be done in less time. Thus it came to pass that the *Screwer* of to-day is greatly superior to his predecessors, by performing at one cut what formerly required several.

The above remarks upon Screwing Machines refer to those employed upon bolts say from ½" to 3" diameter. For larger screws, however, up to about 16" diameter, and 70 feet in length, the work of the lathe must ever reign supreme.

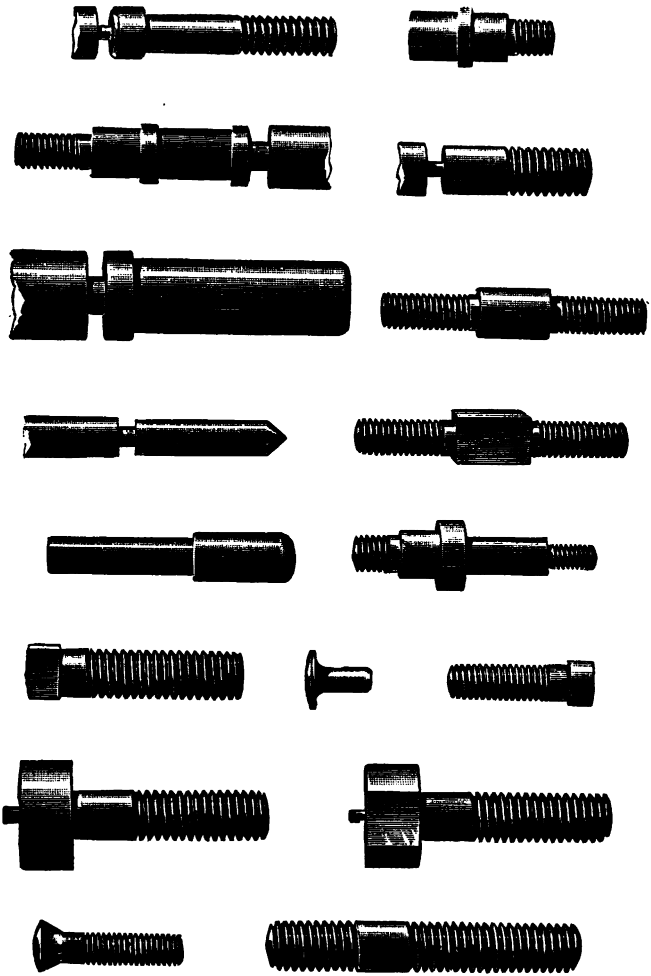
Wood Screws are so extensively employed for innumerable purposes that a cunningly devised machine is used by means of which their peculiarly shaped threads are *rolled* out of a solid red hot steel blank in a very rapid and perfect manner, thus producing stronger threads than when cut by a tool, and saving at the same time about ten per cent. of material.

For operating upon the innumerable varieties of brass fittings and small details used throughout the realms of engineering, the *Hollow Spindle, Capstan*, or *Turret Lathe* is of paramount importance, as each of its six or more tools in rotation can be brought instantly

into play, thus avoiding the loss of time formerly incurred by having to change them for every, perhaps momentary, movement. By the assistance of this machine immense quantities of studs, lever pins with heads and screws, special bolts and screws, etc., are formed at one setting out of rolled bars, which are passed through the hollow spindle of the head stock, and held fast in position by conical grips.

Some of these machines, by Mr. Alfred Herbert, of Coventry, have been so much improved as to be capable of astonishing performances, owing to the skill displayed in the construction of their turrets and slide rests, and also in the arrangement of their tool-holders and tools of great variety to suit endless kinds of rolled, forged, or cast work, either in separate turning, boring, screwing, notching, cutting, chamfering, etc., or in combined form when required. Moreover, when the action of several tools in consecutive order is needed, they can, when properly set in position, automatically perform all the required operations without the aid of a skilled attendant. Without, even, the usual measuring and callipering, every detail will be interchangeable.

Examples of work done on rod steel by the admirably designed *Capstan Rest Chasing Lathes* of Messrs. Smith & Coventry, of Manchester, are given on the next page. It will thus be seen that the former expensive processes of forging and machining such details, which my contemporaries and also myself well remember, have been most successfully dispensed with.



SPECIMENS OF WORK ON ROD STEEL BY MESSRS. SMITH AND COVENTRY'S PATENT CAPSTAN REST CHASING LATHES.

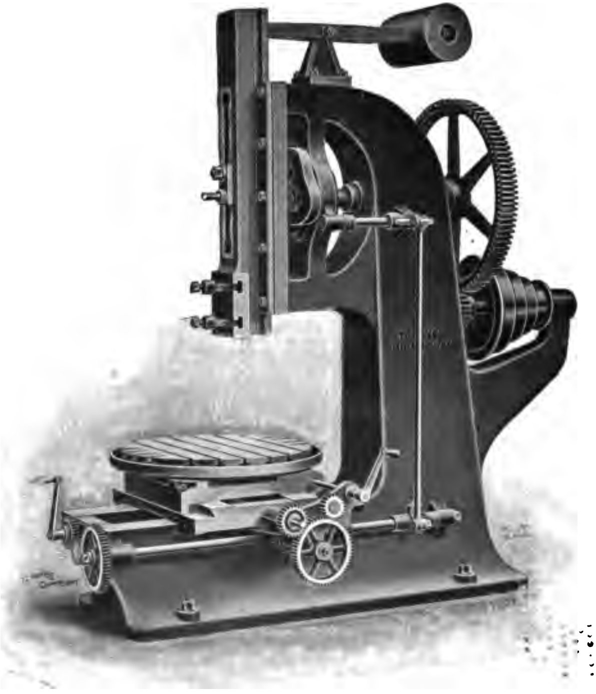
After what has been said about planing machines, it is hardly necessary to make any observations upon the *Slotting Machine* by Messrs. Tangye, shown in the next Plate. As a vertical and partially circular planer it is extremely useful. With a ripping tool in position it is still more so, but when occupied upon work which no other can accomplish, it is simply invaluable. It has an enormous sweep of operations, and applications, and dimensions, from those of 6 inches stroke up to the prodigious *Combined Wall Planers and Slotters,* whose stroke for the former sometimes reaches 18 feet, and for the latter 14 feet, to suit immense castings. These, however, are of entirely different design.

The 12 inch stroke machine before us is a beautiful specimen of its class, and I am delighted to add that the artist has so photographed it that the reader can mark, learn, and inwardly digest every detail and every movement to his, or her, supreme satisfaction.

The foregoing remarks upon lathes, planers, shapers and slotters, have reference to machines whose special feature is the power of taking more or less heavy cuts. We now, however, come to those of a totally different kind.

The *Milling Machine,* to which we refer, is peculiarly adapted for performing a great variety of delicate and interchangeable work that cannot be so well or so economically done by any other process, without the intervention of highly skilled labour.

This tool has been employed in England for about



SLOTTING MACHINE—12 INCH STROKE.

one hundred years, but until recently only on a limited scale, owing to the difficulty and expense of softening, sharpening, and re-tempering the cutters, the last of which processes frequently twisted them out of truth. Now, however, the introduction of emery grinding machines has enabled their teeth to be easily and accurately trimmed to standard sizes without being softened, thus forcibly exemplifying the immense benefit that may be conferred by one good invention upon another. At the same time it should be stated that various alterations in the original form of the teeth enable this result to be accomplished.

Although the miller is, after all, only a nibbling machine, it compensates in a great degree for this defect not only by continuity of action, but by a higher rate of speed, owing to the edges of the tool being successively relieved from contact with the metal operated upon, and thus more fully exposed to the cooling action of water. Hence it follows that the velocity of these edges may be much greater than that of other tools of the ordinary description.

Advancing practice is gradually showing how the milling operation can be most efficiently performed under extremely varied conditions. The same practice is also indicating the necessity of designing details, when possible, to suit the powers of this machine, instead of the lathe, planer, and slotter conjointly, as is generally the case. As screw-cutting lathes are provided with tables of change wheels for various pitches of thread, so

that the turner can see at a glance the required arrangement of gearing, milling machines should be similarly furnished with tables giving the number of revolutions per inch of feed for cutters of all diameters, and depths and widths of cut—roughing and finishing—for brass, cast iron, wrought iron, and steel, the value of which has now been extensively appreciated.

Specimens of a variety of these cutters in general favour, made by Messrs. Tangye, are adjacently shown, as well as some of those invaluable tools of the reamer class. The cutters illustrated can be used either singly or in endless combinations, when fixed on the spindle of a machine, to suit the work to be done. This may be of a plain, inaccessible, and sometimes very irregular form, from the cutting of the teeth of wheels, or threads of screws, or the simple finishing of the edges of cranks, cranks, levers, etc., to work which may be very difficult to execute in any other way.

Although the milling machine is now being extensively used for the heavy classes of work, its powers are most fully shown in places where, perhaps, countless thousands of small details are made from solid blank forgings or punchings. So all-powerful is this machine in its own way, that there appears to be an ever widening field for its employment in every branch of engineering. This is due to the fact that a milling tool has many cutting edges, which have, in finishing to gauge, so little to do that they cannot deteriorate perceptibly, whereas the ordinary finishing tool, when

MILLING CUTTERS, REAMERS, AND COLD STEEL SAWS.

operating upon delicate objects, is so constantly exposed to wear, that its exactness is soon destroyed.

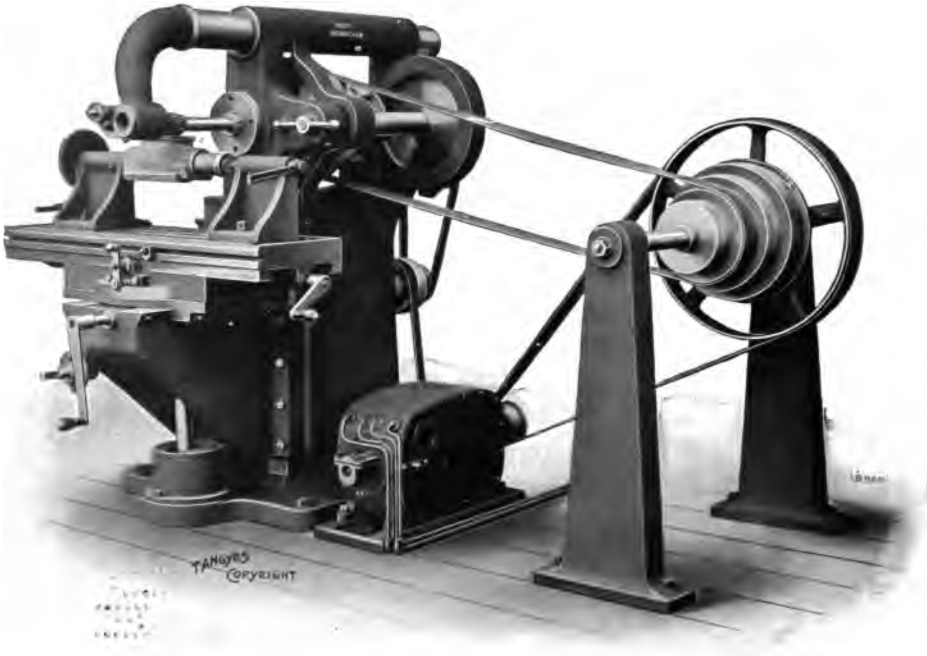
As the cutting of wheel teeth out of the solid is now extensively adopted, it is necessary to have machines which will do the work economically and well. Very many of these are now in successful use, having in some cases three or more cutters employed at one time, according to the size of the wheel and pitch of its teeth, every movement being so arranged that when the work has been set in position and the machine started, it will automatically and unerringly go on to the end without any attention. To show its capability we may add that, whilst cutting three teeth at one time, it will finish a cast steel wheel, 23″ diameter and 1″ pitch, in from 2 to 2½ hours. This is one of the latest and best refinements in spur and bevel wheel gearing, for which also special machines have been designed, the old style of *casting* the teeth, which so long reigned supreme, not being considered accurate enough for the high-science practice of to-day, which has been applied generally to the machines illustrated throughout this volume, as well as to most others.

The applications of the Miller are almost endless, but the following examples will be sufficient to indicate their nature to some extent. Every apprentice knows the difficulty of planing connecting rod flanged brasses in such a way as to require the least amount of hand tool fitting; by the application, however, of the above process, the work is done to perfection without further

trouble. A much more difficult performance is the planing of accurate channel grooves out of solid castings for the slipper guides of small piston rods. Here, again, in the simplest manner, the Miller will, with two cutters in combination, perform this operation faultlessly to gauge. With one cutter it will also cut screws, worm wheels, spiral springs, and so on endlessly.

To enable a clear idea to be obtained of the marvellous powers of this class of machine in its multitudinous forms, upon *minute* details, one would require to visit places, such, for instance, as the splendid establishment of the Lancashire Watch Company, at Prescot, near Liverpool, the gigantic works of the Singer Sewing Machine Company, on the Clyde, and many others, in all of which the most delicate workmanship is executed in a style absolutely unapproachable by any other system. An inspection of various engine, and machine, and locomotive establishments, especially the Crewe Works, will confirm this on a larger scale. Still more will this be the case in marine works, where the most powerful specimens of the miller are engaged in cutting heavy details out of solid blocks of steel.

One of the best examples of this machine, by Messrs. Tangye, in actual work upon a small casting, and electrically driven, is shown in the Plate opposite. The work to be operated upon is, however, generally secured to the table, which is automatically traversable in either direction, and also vertically. The feed motions are sufficiently numerous for all purposes, and when face



MILLING MACHINE—ELECTRICALLY DRIVEN.

cutting is needed, a cutter block is secured by bolts to the flange shown in the view, the overhanging arm being turned upwards or removed for convenience. In this case the wheel gearing is shown cased in for the protection of the attendant.

As it is necessary in the Crewe Works to have complete and easy control of all the *outside* as well as the inside operations, lines of ordinary railway, some miles in length, traverse the area in every direction, and thus maintain a continuous connection with the main line. Besides these, there are about five miles of 18″ gauge line, worked by tiny locomotives which draw miniature trains, conveying materials and finished work from one part of the premises to another.

In thus concluding the last of the chapters upon the above Works, I feel myself standing only on the verge of a theme so world-embracing, so complicated, so fascinatingly intellectual, that I could go on indefinitely. In the briefest possible manner, however, I have endeavoured to give the reader a few facts to build upon, a few ideas to develop, and a few thoughts in the realms of Mechanical Engineering which, I hope, will interest many, benefit others, and throw a few additional sidelights upon Life as an Engineer, reserving to myself the pleasure of indicating, as we proceed, many other features of a career I have myself found so attractive.

CHAPTER XI.

OUTSIDE ENGINEERING LIFE ON A RAILWAY VARIOUSLY CONSIDERED.

How a Line is Engineered in a New Land — Origin of the Liverpool and Manchester Railway—How its great Prosperity affected the Country—Sir Julius Greville, the "Eminent Engineer"—His Pioneer Movements in Baratania—Plotting the Deephaven and Bathurst Railway—Leading Considerations—General Exploration of the Country—Marking out the Line—Value of Trial Borings—A Railway Contractor's Education—His Difficulties—Mr. Brassey as a great Contractor—How Brown, Jones & Co. won the Baratanian Contract—Commencing Operations—Sir Sancho Panza, the Governor, and his Lady—Cutting the "First Sod"—Curious Features of the Canadian Pacific Railway—Its Splendid Engineering—Crossing Three vast Ranges of Mountains without a Tunnel—Its Wonderful Success—How a Wilderness became a Garden.

FROM the previous chapters upon the Crewe Works, the nature of the duties of those employed in them may be clearly understood. There is, however, very much *outside* of these and similar establishments which falls within the province of the *Railway Engineer*. While, on the one hand, the Locomotive Superintendent or Chief Mechanical Engineer, and those of his staff carefully supervise the rolling stock and all that pertains to it in their multitudinous forms, and also the machinery of the line in general; the Railway Engineer-in-Chief and *his* staff take charge of the permanent way, from its

initial survey all through its construction, including the bridges, viaducts, cuttings, embankments, tunnels, stations, etc., until completed.

After these performances have been accomplished, the maintenance of the works in perfect order, by day and by night, will occupy their best attention, and thus enable the railway travelling for which *they* are responsible to become "the safest of all occupations," as the late Sir Edward Watkin so emphatically and authoritatively declared.

To show how, to a limited extent, this is brought about, let me invite the reader to come with me to the large and salubrious, but fanciful Island of Baratania, in the Pacific, where only recently valuable minerals and many other good things were found in immense quantities. When the news of this discovery was flashed throughout the globe, English and Scotch and Irish, Norwegians, Swedes and Danes, etc., made a rush upon the Island by all the available steamers, very many of them hungering and thirsting for the prosperity which their most persevering efforts had not been able to obtain. What a rush, indeed! They all made to the seaport of Deephaven, anxiously desiring to begin a new life in a new land under encouraging auspices, and where they could pass the age of forty without being considered too old for good work.

In the course of their peregrinations, our Government engineers discovered that, at a point thirty-two miles inland from Deephaven, on the banks of the River

Derwent, coal and iron could be obtained in large quantities, and that some of the plains were admirably adapted for farming pursuits and for cotton growing, while other parts were richly wooded, the whole country, indeed, offering the greatest inducements to prospective residents. Hence, in a very short time, large and small tracts of land were appropriated.

On the new arrivals of all classes came in their thousands, by steamboats up the river, by cart and wagon, on horseback and on foot, from day to day. The continued felling of trees, the sound of the axe and the hammer, and the music of the anvil prevailed on all sides, until, at last, the town of Bathurst arose where a short time before not even a hamlet existed. As time rolled on, it increased by leaps and bounds. Its products required an improved outlet to the sea. The original tramways had proved insufficient for a rapidly advancing traffic, hence it became necessary to provide a standard line of the usual type. Thus was originated an undertaking which subsequently became known as the *Deephaven and Bathurst Railway*.

There is, perhaps, hardly anything that has had a greater effect upon the prosperity of countries than their *Internal Communications*, either by road, rail, or water, separately or collectively. Nowhere has this been more conspicuously visible than in the Manchester and Liverpool districts, whose rapid progress in recent times may help to throw light upon our new territory as its resources become developed.

In the year 1760, the roads around and between the above cities were so wretched as to become frequently impassable, the result being that the trade of Manchester, found its way on pack-horses to the Severn, down which it was floated to Bristol. The Duke of Bridgewater, who at that time ardently studied engineering under Brindley, noted this, and proposed to connect the two towns by means of a canal which, in course of time, he actually constructed.

As Manchester had thus a direct outlet to the sea, its trade went up with a bound. Lancashire manufacturers flourished to an enormous extent, and the commerce of Liverpool was similarly benefited, the Bridgewater Canal ultimately bringing in a revenue of £100,000 a year to its proprietors.

Owing to the frequent blocking of the Canal through excess of traffic and also ice in winter, goods were sometimes most inconveniently delayed in transit. With the object of remedying this unendurable evil, the Liverpool merchants resolved that George Stephenson should be applied to for advice on the subject. Having already gained useful experience on previous colliery lines, he immediately proposed a *railway*, the very idea of which greatly dissatisfied the landed proprietors, the little villages and towns, and all the country houses of Lancashire, owing to the "serious evils it was sure to bring." The most strenuous opposition, however, came from the Duke of Bridgewater's people.

The surveyors of the proposed route had a rough

time of it wherever they went, and by the merest chance the scheme was passed by Parliament. The line was accordingly commenced, and thus began the Liverpool and Manchester Railway, which, with Stephenson as engineer-in-chief, was successfully opened on September 15th, 1830, and, through the fabulous prosperity that almost at once attended it, set everyone on fire for similar undertakings. At this period, lawyers and engineers quickly made large fortunes, and sometimes received immense fees, not only for their professional labours, but also for withholding their services from rival companies who wished them.

As a good example of the former, it may be mentioned that the late Sir John Fowler, when a young engineer, was so fully occupied, that on one occasion he actually declined a fee of £20,000 paid in advance if he would undertake the preparation of the parliamentary plans for a new railway, and have them ready within three months. A famous Q. C. also had £160,000 thrust upon him in various ways in four years.

The first practical movement in connection with the Deephaven and Bathurst railway, was the special survey of the country between those two points by the eminent engineer, Sir Julius Greville, of London, who was requested to survey and report upon the undertaking, and plan the best means of economically rendering it most useful to the greatest number of people. This, Sir Julius had done with great clearness, and with that

highly accomplished practical reasoning which had made all his projects very successful.

It may, perhaps, be well here to state that before the route of a proposed line can be decided upon from a *traffic* point of view, the following considerations, amongst others, have to be taken into account:—

(1.) The relative importance of the various towns and villages which lie, or may lie along its course, and the traffic that may be expected from them.

(2.) The character and resources of the district, whether agricultural, commercial, or manufacturing.

(3.) The number and nature of the population at various points, and all other useful statistical facts that may be collected from the most trustworthy sources.

If now, on a large map, a pencil line is drawn from one terminus through the most suitable localities to the other terminus, a fair preliminary idea of the direction of the railway will be obtained. Formerly, people did not much care for some of the intermediate towns, if they could thus obtain a more direct route between the termini, as they trusted to future branch lines from the former coming to their aid. Even, however, after all these have been allowed for, the engineering peculiarities of the case may require deviations from the desired course for the sake of economy in construction.

The obstacles which arise from this cause alone are

sometimes of a serious nature, the engineer's aim being to cross rivers at the most convenient spots, while hills and mountains have to be skirted, or tunnelled, or passed over by means of a series of more or less steep inclines. All places where land is expensive have to be avoided as much as possible, and a general estimate formed of cuttings and embankments, so that they may balance each other as closely as possible, and thus enable the latter to be constructed out of the excavated material from the former. During the progress of an extended survey, all these, and numerous other features are made clearly discernible, the usual system of operations being as follows:—

A General Exploration of the country is made with the view of ascertaining, in all round fashion, the facilities obtainable for the proposed undertaking, and also for approximately determining its best course or direction. During this preliminary process, the geological nature of the country will be carefully studied, and the sources from which various constructive materials may be obtained, also other points affecting the practicability and cost of the line.

Having thus outlined his railway, the engineer proceeds to make a more exact selection of its site by means of *Preliminary Trial Sections*, which are obtained from a series of lines of levels in which distances, as well as heights, are taken, and which may be accompanied by a rough survey and plan.

When these operations have been performed, and

the site of the line more or less accurately determined, the *Detailed Survey and Plan* may be proceeded with. Inasmuch, however, as the previous surveys have been merely of a tentative character, this new one, aided by additional trial sections, will be a more elaborate and exact production, and confined to the small amount of land finally selected for the site of the railway.

The next movements consist in the *Marking out of the Line;* the preparation of details and sections; trial excavating and boring, to enable the nature of the strata in relation to future cost of working to be ascertained; the preparation of the required working details, and general drawings of the line and its structures, in accordance with Board of Trade requirements; the taking out of the quantities of materials; the preparation of the specifications; and, indeed, everything else that can in any way aid the engineers and the contractors in forming an exact estimate of the difficulties to be encountered during the progress of the work, and also its cost, have to be carefully considered before the railway can be commenced.

When the extent and nature of all the embankments, cuttings, tunnels, gradients, curves, bridges, etc., have been thus allowed for, elaborate advertisements invite contractors to send estimates to the Consulting Engineer, or to the Secretary of the Company, for the construction of the line either as a whole, or in sections, according to the extent and nature of the undertakings. As the conditions, however, are rigid, and the enterprise one

that may involve considerable risk from various causes, a great deal of care has to be exercised by those who offer to become responsible for the performance of the work. Before, therefore, a contractor can make out his estimates, he must carefully examine the drawings and specifications, etc., at every point.

The necessity for doing this may be gathered from the fact that a line may run for part of its course over territory which enormously increases the cost of the work at certain places. Sometimes, too, disagreeable discoveries are made which it is impossible to foresee; the Kilsby tunnel, for instance, costing about four times the contract price, because a quicksand was found in its interior, between two borings, which involved enormous additional labour. Incidents such as these help to throw light upon the perils that beset vast undertakings in which the risk may be great.

From these it will be seen that a contractor's education must be not only extremely varied, but eminently practical, as he has to battle with the forces of nature, and successfully overcome them by means of machinery and appliances that will best facilitate excavations and constructions in earth work; the crossing of rivers and morasses; the tunnelling of mountains; the building up of vast works in timber, and so on.

Having satisfied himself regarding the physical features of the undertaking, the contractor must base his estimate upon the current prices of materials delivered at his works, or at various required sites.

The cost of workmanship due to existing wages must be carefully considered, and allowances made for any contingencies that may arise through unexpected fluctuations in the prices of materials, or through engineering difficulties that are impossible either to foresee or prevent, and in addition to these he must protect himself from the evil effects of strikes.

If the railway is to be constructed in a foreign country, the qualities of the labourers of various nationalities, and perhaps the difficulty of obtaining enough of them in a time of need, have to be taken into account, otherwise the contractor's association with that far off land may eventually produce most unhappy reflections. The salaries of his staff, and his own reasonable profit, have all to be considered, as well as many other points of minor importance, and when all is done that can be done, he may in the end lose the contract, because his estimate was *not* the lowest. In this way, we are told, Mr. Brassey unsuccessfully tendered, during his life, for work representing a total value of £150,000,000.

In proof of this we have only to read the *Life and Labours of Mr. Brassey*, by Arthur Helps, which describes the career of a princely contractor whose very numerous works at home and abroad were sometimes on such a colossal scale, and of so complicated a nature, as to produce serious technical and financial difficulties. The fall of a viaduct; an earth work or tunnel turning out much more expensive than was expected; scarcity of labour; malarial ravages amongst the hands; and

political changes of an adverse nature, being only a few of the evils he had to deal with more or less.

As an example of the latter, it may be said that when Mr. Brassey was engaged upon some of the Indian works, the estimates for which were based upon prices that ruled before the commencement of the Mutiny, the extinction of that revolt created so much activity in all the departments of labour after a period of enforced stagnation, that wages went up at least 30 per cent., and even then, the desired number of men could not be had. The most serious combination of adverse circumstances, however, occurred in 1866, when his troubles from a variety of sources, sufficient to have overwhelmed any ordinary individual, came upon him with a rush. Indeed, the liabilities flooding in upon Mr. Brassey, in that most eventful year, were so enormous that it was surprising he eventually emerged in safety from them; devoted friends, however, stood by and helped him most kindly, until he passed through the dark cloud of adversity into the sunshine of prosperity.

Besides his merely technical qualifications, Mr. Brassey possessed the gift of organisation to a marvellous degree, and also the power of anticipating the results of various movements with great accuracy and clear sightedness. He selected his agents with consummate care and judgment, and while he himself was a master of details, he left these to his subordinates in such a way as to allow him perfect freedom in supervising numerous simultaneous undertakings at home

and abroad. He was very generous towards those he employed, and in matters of dispute was equally so. His temperament was singularly calm and equable, success or failure, even great failure, seldom discomposing his serenity of mind, and while he eventually acquired an immense fortune, few could have cared less for the money itself.

Taken for all in all, therefore, Mr. Brassey was one of those truly good and great men who have left their footprints on the sands of time, footprints which perhaps another, some forlorn and shipwrecked brother—or sister—seeing may take heart again.

When our Baratanian scheme had been carefully matured by Sir Julius Greville, and when the estimates from various firms had been examined and commented upon by competent judges, those of Messrs. Brown, Jones & Co., of London, were accepted, not because they were the *lowest*, but owing to the fact that it was well known that their slightly higher prices would be counterbalanced by superior all round excellence in construction. This, Sir Julius had emphatically pointed out to the directors, who quite agreed with him.

Upon being informed of the result of their labours, the above firm immediately engaged a sufficient number of skilled hands, and obtained the necessary machinery and appliances for enabling them to commence operations. All these were shipped without delay, and eventually arrived at Deephaven in safety. Of course, this projected undertaking had been for some time past

the main topic of discussion on the island, now, however, that the executive staff had actually arrived at the scene of operations, the greatest enthusiasm prevailed on all sides, from Sir Sancho Panza, the wise and excellent Governor, down to the humblest individual.

As the commencement of a railway consists in what is termed the "*Cutting of the First Sod,*" it is only natural that this important event should be hedged about with the most pleasant and auspicious circumstances. Hence, when it became known that arrangements had been made for the due performance of the ceremony on the following Tuesday, everyone seemed to consider that he or she ought to bear a hand in giving effect to the proceedings.

The grand day was one of sunshine and splendour, and everyone was on the move from an early hour. An air of "gr-r-eat excitement" seemed to pervade the whole population, and all the available flags were hoisted in conspicuous positions afloat and ashore, thus producing a very charming effect.

By twelve o'clock everything is ready, including the external and internal embellishments of a large marquee which has been provided for the visitors and others. A procession, headed by a band of music, marches to the spot where the First Sod is to be cut, around which the assembled company forms itself into a circle, the central portion being occupied by Sir Sancho and Lady Panza, and the most prominent of the inhabitants and officials. The Chairman of the Directors now delivers an address,

in which he clearly shows to his admiring audience the immense advantages to be derived from the railway when completed, and points out the probability of a very large population being drawn to its adjacent territory, in addition to the rapidly growing passenger and goods traffic now waiting for it. Finally, he alludes in most felicitous language to the honour conferred upon them by the presence of the Governor and his Lady, "to whom they already owe a debt of gratitude."

Upon finishing his oration he presents Lady Panza with a handsome spade of silver-mounted polished mahogany, and after receiving the necessary instructions, she commences the ceremony by pressing the spade into the earth and throwing a small detachment of it into an adjacent barrow of polished oak, exquisitely mounted in silver. The Governor now throws off his coat, and amidst the enthusiastic cheers of the multitude, fills the barrow, and then wheels it away, after which he leads the company into the marquee, where an elegant luncheon has been prepared. After a few speeches have been made, and replied to, Sir Sancho and Lady Panza depart amidst tremendous cheering and the firing of naval guns worked by blue jackets, taking with them at the same time the barrow and spade with which they had inaugurated the first grand undertaking in their island home, and which was destined to produce magnificent results in the future.

The phrase, "a line of railway," is one that has a very elastic significance, as it embraces so many more

or less diversified physical peculiarities in the country through which it passes. The least expensive arrangement is one that in a straight line traverses flat territory, since, in cases of this kind abroad, the sleepers are simply laid on the ground with a trench on each side to carry off the surface water, an interesting example of this being the Argentine Pacific Railway, which runs for 211 miles without a curve.

At other times a line may consist of only moderate gradients and curves, or, if in a hilly country, of slopes and windings of a more pronounced and frequent nature. In a mountainous region, however, not only are the two latter in great demand, but embankments, cuttings, and tunnels, sometimes of great length and most difficult construction, are additionally employed, as well as bridges and viaducts of every conceivable form and dimension. In short, a railway between two distant termini, may include many of each of the above, according to the physical peculiarities of the country through which it has to be carried.

As the *Canadian Pacific Railway* is one of the most gigantic undertakings of this description, we may here refer to a few of its leading features, to which those of our new line will be very similar, though in a small degree. Formerly, the country through which it had to pass was unexplored, and included a vast region where many deep lakes and great rivers existed. For 1,000 miles beyond the Red River stretched an immense plain, then came the mountains, range after range in

succession, and through all this territory, for a distance of nearly 2,000 miles, the engineering surveys had to be made at a great expenditure of time and money.

These surveys for the railway had exposed the character of the country it was to traverse. In the wilderness bordering on Lake Superior, forests of pine and other useful timber, mineral deposits of incalculable value, and millions of acres of agricultural land were found. The vast prairie land between Winnipeg and Rocky Mountains proved to be wonderfully rich in its farming resources. Towards the mountains great coal fields were discovered, and British Columbia was known to contain nearly every element of wealth. Hence there was no difficulty in finding people ready to relieve the Government of the undertaking it had initiated, and carry it on as a commercial enterprise.

In this way the Canadian Pacific Railway Company was formed in 1881, and immediately afterwards entered into a contract with the Government to complete the line within ten years. The work of construction was therefore vigorously commenced at Winnipeg, and pushed westward at great speed.

Some idea will be formed of the rapidity with which a prairie line may be laid, when it is known that for months in succession the average rate of advance by the Company's staff was from three to six miles a day. By the aid of armies of men having all the best appliances, and thousands of tons of dynamite, the end of the third year found the railway at the summit of the Rocky

Mountains, and the fourth in the Selkirks, nearly 1,050 miles west of Winnipeg, the Government section of the line from the Pacific coast being swiftly carried on until both forces met, on November 7th, 1885, and the last rail was laid.

By the middle of 1886 all this vast system was in full working order. Villages, towns, and cities closely followed the constructors. The forests were cleared away; the soil of the prairie was turned over; mines were opened; and even before the last rail was in its place, the completed sections were carrying a large and profitable traffic.

From the foregoing remarks it will be seen that the Canadian Pacific Railway, now fully 10,000 miles in length, is one which combines in itself many of the most varied and difficult and skilfully executed features of engineering practice, including the crossing of three great ranges of mountains, without a tunnel, in British Columbia. It also shows, on a prodigious scale, how an uninhabited wilderness may be so altered as to become a fruitful garden, and the nucleus of vast and thriving populations. These remarks upon the grandest engineering and commercial enterprise of the age will also accentuate much that will be further said concerning our Deephaven and Bathurst railway.

CHAPTER XII.

CONSTRUCTION OF A NEW LINE IN A NEW LAND.

Various preliminary Movements—Earthworks and their Peculiarities—Railway Construction—Sleepers and their Treatment—Chairs and their Design—Rails and their History—Heat Expansion and its Dangers—A Heat Expansion Story—The Baratanian City of the Future—Speculator's Drawings—"Magnificent Town Plots"—"Streets," "Squares," and "Crescents" from the Old Country—Cuttings—How excavated by Mechanical means—Embankments—Curious effects of bad Foundations—A Great Day for Baratania at hand—The People jubilant—A "Most Awful Disaster" on the Line—How remedied—The Opening Day—Unbounded Enthusiasm of the People—Bathurst in a state of Flutter—Starting the First Train—Arrival at Bathurst—Sir Sancho and his Lady again "Bossing the Show"—The Festivities—Line open for Traffic—Prodigious Development of Baratania.

IMMEDIATELY after the ceremony of cutting the first sod had been successfully performed, Messrs. Brown & Jones began to make preparations for starting the works, and with all the more energy as the contract stipulated that while, on the one hand, a premium should be paid to the builders for every week of completion before the specified time, a penalty would be enforced for delay *beyond* that period.

For the sake of making the line more interesting,

let us suppose that it includes a few level portions, extremely varying gradients and curves, cuttings, embankments, tunnels, and viaducts; primeval forests that have to be penetrated; and a series of bridges of diversified kinds. All these have been more or less formidable obstacles on innumerable railways, and as they will still be on many others, we hope to show, as we get along, how the work is accomplished.

The term "*Earthwork*" is generally applied to excavations or cuttings, and embankments. Cuttings are of an extremely varied nature, and may be, on the one hand, of the most trivial dimensions in mere earth; or, on the other hand, of the most gigantic and costly description in the hardest granite, etc. In addition to the ordinary difficulties that are usually met with in any great undertaking, may be mentioned the exposure of the sides of deep cuttings to landslips, owing to the unexpected presence of water, which has often caused great trouble and delay. For instance, at a certain place on one English railway it was calculated that about 50,000 cubic yards of earth would have to be removed, but upon the severance of a seam of shale that supported the superincumbent earth, the latter slipped to the bottom of the cutting, thus involving the removal of no less than ten times the above quantity of material. The undesired presence of water, too, has often proved most disastrous to the works, and those who remember the difficulties encountered by the contractors of the Manchester Ship Canal, will realise, to

some extent at least, the secret sources of danger to be met with when least expected.

One of the most remarkable cuttings in *rock* is that of the "Olive Mount," on the Liverpool and Manchester line, where, for nearly two miles, the railway traverses an artificial ravine with perpendicular walls in some places more than 100 feet in height. Naturally, we should have expected a tunnel at this point, but various considerations prevented it, one of them being that the stone was required for various works along the line, thus providing constructive materials without the trouble and expense of getting them from distant sources.

After everything has been done to secure the best practical results, and, indeed, after the sides of cuttings have stood for months, or even years, they have at times either loosened or slipped owing to chemical action alone. Slips thus created might be supposed by an ordinary observer to be due to want of care or skill on the part of the engineer. With some materials, however, the action of time and weather occasionally produce changes of this nature that are almost irresistible, thus forming serious dangers which cannot well be avoided.

The most rudimentary of all railway constructive performances is that of laying a line upon a level plain, nevertheless, certain precautionary measures are necessary to avoid future failures. Of course some may imagine that placing the sleepers on *bare* ground

is quite sufficient, but this might cause them to rot and endanger the traffic of the line. To avoid these evils, the sleepers are bedded upon a layer of broken stone, carefully laid on the top of the earthwork, thus producing a foundation through which the water percolates into a drain upon each side of the line. This stone is, to some extent, broken by a machine which may, when of large size, crush twenty-two tons of the hardest rock per hour.

The *Sleepers* are sawn in prodigious quantities to 9′ 0″ in length, 10″ in breadth, and 5″ in depth. They also have the spike-holes bored through them in the exact positions, so that not only will the chairs or flat-bottomed rails fit unerringly to their places, but every spike will require the same force to drive it home without splitting the wood.

Sleepers, such as these, are generally spaced about 3′ 0″ centre to centre throughout. They also form admirable ties for the rails, whose gauge is maintained more or less perfectly according to the manner in which the latter are secured to them. Various kinds of timber are employed for this purpose, one of the most popular being Baltic pine; all, however, are liable to rapid decay if not sufficiently protected. The *creosote* which ensures this is obtained from coal-tar, and possesses antiseptic properties that prevent the timber impregnated by it from being attacked by worms or insects, etc. When the oil is forcibly injected under severe pressure into thoroughly seasoned wood, it closes up its pores, and

excludes moisture so effectually as to cause the sleepers to last for many years.

When *Chairs* are used they are moulded by special machinery in enormous numbers, the conditions that guide their designers being as follows:—The section of rail and method of keying it to the chair; the system of permanent way employed; the size of the sleeper and the kind of wood; the distance of the sleepers apart; the maximum load on the rails due to any pair of engine wheels; and the speed of the trains.

The *Rails*, to which we now come, have quite a history of their own; those, however, of early design, that were once so popular, have been so completely superseded by two distinct systems which have grown out of them, that to these alone we shall refer.

The immense importance of having our steel roads as perfect as possible becomes clearly apparent from the fact that it is by their excellence at every point, and the smoothness in running this naturally creates, that damage to the ballast, injury to the sleepers, fracture of the chairs, increase of resistance to the passage of trains, crushing, and, perhaps, breaking of the rails, and severe wear and tear of the rolling stock and its machinery, are avoided. Indeed, it may be said that, without the excellence referred to, the statical and dynamical systems of a railway would so rapidly become disintegrated, unless constantly and expensively renewed, and so many terrible accidents would result, that a line which began auspiciously would end disastrously.

As the fish-belly rail of 1820 made a good show in theory, it became popular for a time, but as it was troublesome to make, it was superseded by the flat-bottomed rail of Mr. Vignoles, which has been so much improved in form and proportions as to be the one most in use all over the world. Inasmuch, however, as exposure to severe wear of the top part of the rail made it soon become useless, Mr. Locke invented the double-headed rail, which possessed great strength as a beam, and also the capability of being turned when the top became too much worn. Here, however, theory was again baffled by experience, as the part that rested upon the chair became so indented by the action of the traffic as to render it unsuitable for smooth running when turned.

This led to the introduction of the bull-headed rail, whose top bulb was made larger than the bottom one for the sake of good wear, and in this respect it has answered so admirably as to have displaced its predecessor.

Up to the year 1862, all the rails were of iron, but so enormously had the traffic expanded, and so rapidly had the weights and speeds of engines increased to enable this traffic to be satisfactorily worked, that the iron rails then in use were bent, laminated, and split by the pounding strains they were subjected to. They were also severely worn and torn by the skidding action of the wheels when checked by the powerful brakes, hence the life of the rails was so much shortened

as to indicate the need of the employment of some more durable material. Thus arose the demand for *steel* rails, some of which were so successfully made by the London and North Western Railway Company as to open out a way for others on a greatly extended scale.

These at first were rather costly, but the inventions of Bessemer, Siemens, and others, introducing improved methods of manufacture, so diminished the cost of production as to rapidly change the original iron roads into lines of steel, whose superiority is due to their greater strength and perfectly homogeneous texture, by means of which the faults incidental to iron are avoided. To enable this to be most fully attained, a rigid system of variously testing the materials was introduced, which proved highly beneficial.

Some may perhaps fancy that these tests—chiefly tensional, compressive, and percussive—are of a very exacting nature. It must be remembered, however, that when steel came into general use it had many failures. Rails snapped unexpectedly and imperilled the rolling stock; ship plates similarly gave way; and marine boiler shells cracked and split so mysteriously as to endanger the safety of the ship which carried them.

No wonder, then, that the Companies who transported the public over land and sea carefully noted these defects. So also did the Steel Works people, and therefore it was only natural that various scientists should have combined their talents and energies with the object of rectifying these evils.

But even this was not enough, as the users of the steel, as well as its manufacturers, had no means of satisfying themselves on this point without extraordinary precautions. Therefore, with the past behind them as a warning, the most rigid system of testing and supervision was instituted, which ensured the desired quality of metal, and thus avoided dangers that might otherwise have arisen. Dangers, too, that were intensified by the fact that not only rails, but the engines themselves, and the main metallic parts of the rolling stock, were made in enormous quantities of the new material, the success of which has been marvellous.

If we should pleasantly meander along a railway with two or three non-professional friends, we might expect to have *one* apparent fault of rail laying pointed out to us.

"Very bad workmanship, I should think," observes a lady whilst gazing at the open ends of the rails, and bad indeed we would call it under other circumstances.

Heat, when applied to rails, makes them expand irresistibly during a range of temperature from winter to summer, hence, a visible space is left between the ends of each to avoid dangerous upheavals.

Not only in rails, but in all metallic structures, the above thermo-dynamic law is taken into account, otherwise bridges would become dislocated, and exploded steam pipes would spread death and destruction all round. Other evils, too, of a more or less dreadful

nature throughout the realms of engineering, would be sure to follow, but to these we need not refer.

An Oxford professor on one occasion tried to impress upon a student the fact that heat caused expansion, and cold contraction.

"Tut, tut, man," replied the youth, "I know all that; don't we see it every day by the lengthening of the days in summer and their shortening in winter!"

As previously observed, the most rudimentary of all railways are those which, in pioneer fashion, pass over territories such, for instance, as the prairies of America and Canada, where, for hundreds of miles, they may be run straight ahead without any obstruction. In cases of this kind the ground may be only trimmed to a fair surface, as the population is very small, and the prospects of success somewhat hazy. On our Baratanian line, however, nothing but a substantial system of construction will be suitable, as recent discoveries of agricultural and mineral avenues to fortune, the enormous influx of new residents, the astonishingly swift enlargement of the town of Deephaven owing to the extension of its maritime commerce, aided by light railways, so fully indicate.

With these facts in view, is it to be wondered at that enterprising speculators have already made preliminary arrangements for the building of towns and villages along the route of the line. True and faithful large scale plans of small but suitable portions of the land adjoining the railway have therefore been made, and

upon these have been drawn in detail the proposed positions of villas, streets, squares, etc., such, for instance, as "Windsor House," "Princes Street," "Oxford Street," "Belgrave Square," "Grosvenor Square," "Lansdowne Crescent," and so on, with the object of continually reminding the future inhabitants of the Old Country.

Wherever the hope of coming trade or manufacture has been strong enough, these "magnificent town plots" have been located upon a scale of grandeur that includes broad avenues, beautiful gardens, public buildings, etc. The block plans of all the buildings have been painted with crimson lake, the roads and streets washed with yellow ochre, the trees and shrubs of the gardens painted a darkish green, the grassy parts being lightly tinted with the same colour, and all the water spaces indicated by artistic touches of Prussian blue. As the drawings are also beautifully titled, dimensioned, and finished off so as to look as intelligible and attractive as possible, and the prospectuses, now being extensively circulated, are telling their story most effectually in various countries, the result will probably be a rush upon the spots referred to by the strugglers and others from lands where trade and commerce have more or less deteriorated, and where the prospects of success in life have become narrowed to a point for those who hope to be older, as the history of the Canadian Pacific Railway and many others will abundantly testify.

Although five miles of track have already been

prepared, no earthworks of any consequence have yet been entered upon, as a few gradients have done all that was required to enable them to get comfortably over the inequalities of the ground.

Immediately, however, after passing the fifth milestone on the road to Bathurst, it was found that a *Cutting* had to be made in the side of a hill, but of microscopic importance when compared with that of the Manchester Ship Canal, which was 35½ miles in length, 170 feet in width, and 26 feet in depth at the water line, and having in two places an average total depth of 55 to 66 feet. This prodigious work was eventually completed by the aid of, at one time, 10,000 men and very numerous mechanical appliances, in which the *Steam Navvy* or *Mechanical Excavator*, shown in the next plate, held one of the most important positions. So important, indeed, that it will be used with equally powerful effect on the Baratanian line, its mode of operation being so clearly shown as not to need description.

When a railway has to be carried across a depression of greater or lesser extent, or requires its level to be raised, the system of *Embanking* is generally employed.

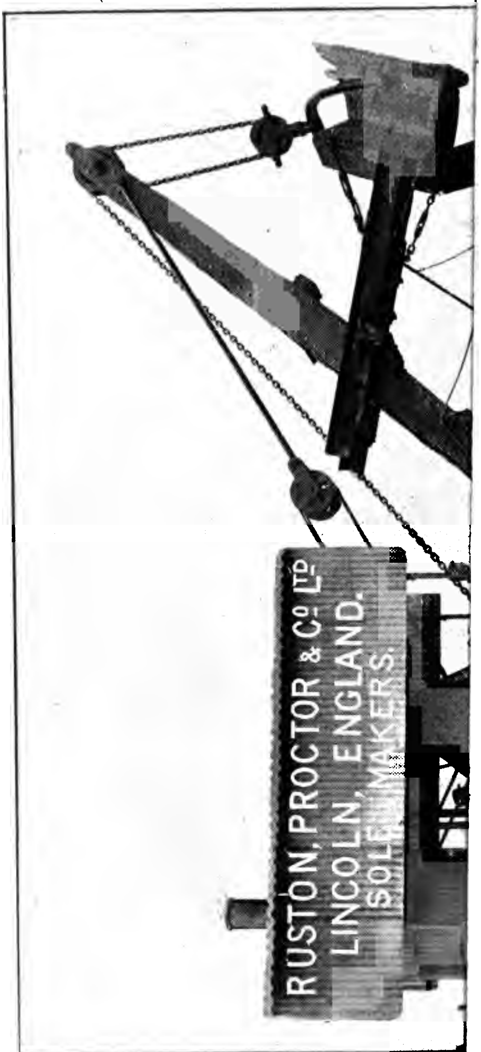
The constructive process is simple enough, each wagon load of earth being run along a temporary line of rails, until suddenly stopped by a piece of timber, which causes the wagon to tip on end and discharge its contents over the bank as the work proceeds. Great difficulties have thus been frequently encountered owing

to the marshy, peaty, or otherwise unsound nature of the ground over which the embankment had to be carried. In some cases, the materials have either been swallowed up as fast as they were deposited, or the work has been seriously disrupted after construction. The most notable example of the former is to be found in the history of Chat Moss during the progress of the Liverpool and Manchester Railway, which to this day is considered one of George Stephenson's grandest achievements.

As a class of railway work, Embankments are among the most important, ranging as they sometimes do up to those of colossal dimensions. They also permeate in various forms the whole domain of Earthwork Engineering, where ground has to be made up or filled in for general building purposes which cannot otherwise be successfully treated.

As the various operations connected with the actual construction of a line in any country have already been referred to, and are quite applicable to our South Pacific undertaking, we may now imagine that those which were necessary have been performed wisely and well by Messrs. Brown and Jones, and that the end is near.

A great and historical day for Baratania is now close at hand. In previous pages we have sketched out the discovery of the Island; the pioneer movements of its inhabitants; the cutting of the First Sod of its initial standard gauge railway, and the various operations that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followed, so that as a picture from life in a new country, or even in new parts of an old country, the descriptions given may be rendered interesting, and I hope, attractive to all. Everything has been carried out and Board-of-Trade-tested and inspected to the entire satisfaction of Sir Julius Greville, the Resident Engineer, the Contractors, and everybody else.

A spirit of jubilation has pervaded the minds of the people for the last week, intensified, of course, by the official announcement that "within a month the line will be opened for traffic." On the following day a tornado burst upon the Island and did much damage. By sunset calmness reigned, but about 9.30 the silence of the streets was broken by the severely discordant shouts of the newspaper selling fraternity who announced a "most *awful* disaster on the railway, many killed and *wownd*ed—gr-r-reat excitement," and so on, which so alarmed the townsfolk that exclamations such as "Good gracious!" "How sad!" "Dear me! is it possible?" etc., were heard on all sides, whilst anxious enquiries were made to the right, to the left, and in every other direction. Late in the afternoon a man had been seen running full speed towards the house of the resident engineer to report the calamity.

"Anything wrong?" hastily exclaimed the editor of *The Deephaven Herald*, as he tried to intercept him.

"Serious accident on the line."

"Anyone killed?"

"None killed."

To the former this appeared to be *nine* killed, and so he logically concluded that many must also have been injured. With these facts as a basis, he swiftly composed an article for the *Evening Special* which would give the anxious crowds some idea of the state of affairs, not, of course, as they really were, but as he himself thought they might, could, would, or should have been to produce such dire results, leaving, however, the corrections to be made when the whole truth became known.

Next day the amended news read as follows:—"During the terrible storm of yesterday a portion of the nearly finished Braemar viaduct was carried away. No lives were lost, nor, indeed, was anyone injured. We have just been informed that the damage is so trivial that the contractors hope to complete the structure within a few days."

Now, how did this accident happen at all, when so much care had been bestowed upon the work? Mr. Brassey experienced disasters of similar nature from pretty much the same causes, on one occasion to the extent of £50,000; and the early Brunel was *just* saved from a worse experience on the Great Western line when constructing it; so let us explain the reason of the Baratanian failure. Messrs. Brown & Jones had been pushing on the works with all speed, and at the same time most successfully. According to the specification, the mortar used in the various erections had been made of the "lime of the country," and this had hitherto proved suitable enough, although not the best for quick

setting. Here, however, the last portion of the above viaduct, which had been built during wet weather, was overtaken by a most violent tempest before the mortar had sufficiently consolidated, the result being that a small portion of the work most exposed to the fury of the storm gave way.

When the "Resident" and Mr. Brown had carefully surveyed the extent of the damage, the latter immediately put some of his best hands upon the work by day and by night until it was completed. A few days afterwards it was officially announced in the *Herald* that, "As the line will be opened for traffic next Thursday, we hope the day will be kept as a general holiday." This editorial recommendation, however, was quite unnecessary.

"Call me early, call me *early*, mother dear, for *to-morrow!* will be the happiest, merriest, brightest day in all this glad new year," was the expressed wish in many a Baratanian home the night before the great event. The morrow dawned in sunshine and splendour. Everyone was on the move from every point of the compass.

Immense preparations had been made to render the scene as impressive as possible. Flags were flying in all directions on land, and the ships in the harbour were profusely decorated in the same manner. The town's folk were already occupying the best positions. Three mile-an-hour bullock drays were coming in from the

country crowded with people in their Sunday best. One horse vehicles, laden with whole families in go-to-meeting costumes were similarly approaching the capital. Farmers, etc., on horse back, and vast numbers of pedestrians were merrily heading for the same spot. On they came in their thousands, until at last the incoming tide had reached its full height.

The tops of the houses, the trees, and every eminence that could allow the train to be seen to the best advantage, as well as the terminus and its approaches, were packed with sightseers. All along the line, too, people were in waiting at the various points of interest, while Bathurst city was in a state of flutter all over, as that was not only to be the end of the outward run, but the scene of the accompanying festivities. Special privileges had been provided for many favoured guests, each of whom was to receive an elegant souvenir.

The hum of many voices—the bustling activity of policemen, and railway officials in their new uniforms—the great variety of crowded vehicles drawn up in lines—the train of handsome carriages—the locomotive, adorned with flags and evergreens, and the gaily dressed passengers who are now taking their seats for the first time, presented a scene which compelled the talented editor of *The Herald* to confess next day his "utter inability to describe adequately."

When all was ready, the starting signal was given to the engine driver, Ronald Macgregor—late of Crewe—and at once the *Sir Sancho* began to move along the

line, to the enthusiastic delight of all, and amidst the waving of hats and handkerchiefs and the cheers of the multitude, the first train left Deephaven on its way to the interior, Bathurst being reached in good time after a smooth and most successful run, which, however, had been insured by means of the preliminary trials which brought everything and everybody into good working order at the outset. From the foregoing remarks the reader can easily fancy the unbounded enthusiasm which prevailed on all sides at this moment at the inland terminus.

"The banquet?" Ah! that *was* a triumph in every sense. Sir Sancho and his Lady were brilliant, Sir Julius Greville was delighted with everything. The Chairman of the Directors seemed to fully recognise his honourable position, and in simple, humorous, and well chosen language, let everyone know how "satisfied *he* was with the proceedings, and how much he anticipated a highly successful future for the line they had now opened. In England," he continued, "the safest occupation of all is railway travelling, but here, in Baratania, it would not only again be the safest, but the most *delightful*, as he and his colleagues would endeavour to make it."

Some of the Directors, and others, including the "Resident," the Contractor, the Locomotive Superintendent, etc., had each something good to say, and when all was over, the company re-embarked in the train to return to Deephaven, and thus ended a day ever

to be remembered in that exquisitely beautiful and happy home of the future for everyone.

Were the Chairman's predictions realised? They were—beyond expectation. The line soon became extremely popular, Deephaven and Bathurst went up with a series of bounds. Mining and agricultural districts were opened out, more or less, in the vicinity of the line. The nucleii of prospective towns and villages were formed along its borders, or within easy distance of them. Trade marvellously expanded. The timber wharf accommodation was much extended. The floating dock, which had done good service in the past, was supplemented by a spacious graving dock. Marine and locomotive repairing works, with plenty of room for future enlargement, were rapidly proceeded with. In short, nothing was left undone which could, in any way, increase the prosperity of the Island we have made the scene of the above performances, and to which, as a native of Hobart, Tasmania, and a resident during early years in Australia, I now affectionately say farewell!

CHAPTER XIII.

HOW I COMMENCED AS A CONSULTING ENGINEER.

Retirement from the Works—First Movements in a New Direction—Advice of Friends—Serious Obstacles—"Too many in the Field already"—The generous C.E.—A start at last—Making good Progress—Hints to those intending to enter Private Practice—Value of Accidental Circumstances—How to succeed as an Engineer—Special treatment of Scientific Literature—Value of Private Note Books—*Entirely* on one's own Resources—How Engineering Drawings are originated and developed—Their leading Requirements—Their Difficulties—Costly Mistakes and their Results—Private Practice as it *was*, and *is*—Overwhelming Occupation of the Past—Evil effects of Over Study—How the late and Great Engineers monarchised the Profession—Gradual decadence of Practice—The Causes—Proposed Remedy.

AFTER a long and very happy association with the Works, I conceived the idea of commencing as a Consulting Engineer, but this proved much more difficult to accomplish than I expected. My first move was to call upon a number of shipowners and engineers in Liverpool, with the object of sounding them as to the possibility of starting on my own account. The former received me courteously. Some said one thing and some another, but all agreed that it would be most difficult to commence at all unless I had something to

"keep the wolf from the door for the first two or three years." The engineers held the same opinion, but in a more marked degree; indeed, one or two of them said it was nearly impossible to do so, as there were "too many in the field already."

Here, then, was a damper at the outset, because I had no one to look to for employment, and was careful about entering upon, what might be to me, heavy office expenditure without any prospect of even a small return for the outlay.

Amongst those I called on was the proprietor of one of the brass foundries, whom I knew well. Upon visiting my old friend, he asked me whom I had seen, and what they had said. I told him.

"Have you seen Mr. C.?"

"Oh, yes."

"What encouragement did he hold out to you?"

The information was given.

"Well, now," said Mr. Marsden, "why don't you start for yourself? There's Mr. So-and-so; *he* began on his own account some years ago, and has succeeded. Then there's Mr. Somebody-else, who did the same thing, and he has never gone back. Go and speak to Mr. C. again, and say I sent you."

On my way to this gentleman's chambers, I met him on the street, and was told that whenever I could get something to do I might have the use of a desk in his establishment. This was very cheering, because the main obstacle at the outset was to obtain a decent office,

and, at the same time, work to begin upon which would help to pay expenses. Up to this period, I thought I had seen nearly all the engineers who were likely to *en*courage and *dis*courage me, but, a few minutes after the office difficulty had been settled, while quietly walking along Dale Street, I saw the name of Mr. Shoolbred—a civil engineer I had not known of before—and immediately called upon him as a sort of forlorn hope. He received me very kindly, and asked if I would help him with some plans he had to prepare for a Hot Air Pumping Apparatus and its accessories, and, upon telling him I would be very glad to do so, they were at once handed over to me.

I went home happy that night, because one of the most fortuitous coincidences imaginable had, in a single hour, removed from my path two apparently insurmountable difficulties, and also opened out my prospects for the future. In other words, I had found an office and remunerative employment, when to all appearance there was not the slightest chance of either.

That generous C.E., who had also an establishment in London, has never, I believe, had occasion to regret having extended a helping hand, and giving the first five guinea fee to one by whom he will always be gratefully remembered. The temporary desk gave place in a few weeks to a permanent office, and, in course of time, I came in for a civil and mechanical engineering practice of a most varied and interesting character. One part of my experience, however, consisted in sailing

tremendously close to the wind, and trying to make headway against the usually small amount of financial success. So hard, indeed, was this species of navigation, that, had I not been possessed of a little private means, there were critical periods in which all my professional experience would have proved unavailing, and I would have been unable to keep to the course I had endeavoured to steer.

This will be easily understood when it is stated that one of our ultimately most successful engineers could only make sufficient to pay his office rent for the first five years. This gentleman I knew well; he, however, had the advantage of a private fortune, which many of our brethren have to do without.

Another friend of mine, who for a considerable period was superintending engineer to a great ocean line of steamers, had £1,000 a year for looking after them, but was obliged to retire on a pension, as his health would not stand such a severe strain. He, however, began on his own account, and notwithstanding the prestige derived from having been successfully associated with so eminent a firm, absolutely failed to obtain any employment connected with ships for more than two years afterwards. In this case, his great ability seems to have been unrecognised on account of his too retiring disposition.

It will thus be seen that even when accomplished engineers commence to practise, their worst difficulty consists in getting work to execute, unless they have

been fortunate enough to secure a few good clients beforehand, and this, in many cases, is almost impossible.

Some may ask why I did not commence private practice sooner. Well, that is easily explained. In the first place, it is very risky to leave permanent and good employment for what may be very uncertain, unless you have reasonable inducement to do so, or have sufficient means. And secondly, so great has this risk now become that people are more or less content to run in a groove until pushed out of it. In other words, we think it safer to bear the ills we know than fly to those we know not of. If the history of some of our most successful men could be analysed, we should find that in many cases they owed their prosperity to some unforeseen movement which threw them involuntarily on their own resources, and caused them to look about elsewhere. Indeed, purely accidental circumstances have often done more to advance people's interests than the most skilful, and long sustained planning could possibly have accomplished, and of this, I myself have had many very happy examples.

To enable engineers to succeed in private practice, or, indeed, in any other way at home or abroad, it is often necessary to have a good general knowledge of the profession outside of the particular branch—say locomotive or marine—that they have been educated to. This will be apparent when the difficulty of securing occupation is considered, and therefore it is to one's

advantage to be able to direct the mind to other lines of thought and practice when possible.

For reasons already stated, the locomotive branch can only give experience of a limited nature, and does not allow of much expansion. On the other hand, *railway* engineering has a very extended sweep, and embraces a great variety of most interesting subjects, such as earthworks, brickworks, and stoneworks — bridge building — roofs of all sizes — steam and hydraulic machinery of every description — constructional ironwork, such as girders, columns, etc., and a thousand and one other things most necessary for the safe and economical working of our steel roads. Marine engineering is also of a similarly varied description, so varied, indeed, that people with fair talent and a certain amount of adaptability to different pursuits, may easily take in hand work of a general character.

To those who have time and opportunities, no difficulty need exist on such points, because there are now so many avenues of information open to all who wish it. People who venture upon private practice, however, will soon find out, unless possessed of powerful influence, that for the first few years, they will have a great deal more spare time than is desirable, and may frequently be at a loss to know how to occupy themselves advantageously. In small towns this will no doubt be severely felt, but in large cities it need not be the case, when a valuable library, and plenty of good magazines may be within easy reach, from which an

immense amount of professional knowledge may be obtained, and thus provide much that is interesting, and perhaps profitable in the future, especially when, as a general practitioner, you may be asked at any time to perform work which is quite new to you.

The engineering literature of the present day is most extensive and practical, so extensive, indeed, that a student may often be unable to know what to do with it. It may therefore be broadly stated that, if only a small portion of the really useful books and periodicals were carefully studied, no time would be left for anything else. Of this I soon became aware, and therefore employed the following simple system of notation, which in various forms is well known, I should think, in many of the professions.

Read carefully everything that bears directly upon what may be your own practice in the near future; pick out simple formulæ which are *not* given by Molesworth, or Hurst, or D. K. Clark. Analyse minutely the results of experiments on various metals, timber, and other substances, also any other useful information which may be gleaned from the great mass of books and periodicals, and enter your notes in private pocket encyclopædias.

In the next place, glance at, more or less intently, any number of volumes you please of a kindred nature, and transfer the titles of their contents very briefly as aforesaid. If this is done as the years roll by, an enormous amount of valuable information will be at

hand for immediate and special reference, which may tide the engineer over many critical points, and enable him to work rapidly and confidently. These note-books should be well bound in soft leather, stepped down at the edges, and red lettered, with so many pages to each letter, according to expected requirements, and every entry should be as brief as possible. Notes from professional and general literature, however, should—for easy reference—be kept separate from the invaluable sketches, tables of detail proportions, and simple formulæ obtained from actual practice.

Since calculations and statements referring to work in progress are so important as to involve the possibility of much trouble unless clearly understood, the engineer would do well if he compared one authority with another, and endeavoured in every possible way to obtain a rational interpretation of formulæ which so often appear to be empirical, but are nevertheless based upon scientific reasoning. Our opinions—like those of medical gentlemen and also lawyers—often differ in detail, but vital principles in design and construction are the same everywhere, and cannot be too closely followed out.

The above remarks refer to my own practice, of which I have now had long experience, and the value of the hints given may be gathered from the fact that, when an engineer is adrift from the designing staff, with all its fully organised advantages, and with which he has been many years associated, he is thrown entirely

upon his own resources. These may be of a most comprehensive and satisfactory nature, or otherwise, according to the manner in which he has spent his time as an apprentice, and, subsequently, as a staff assistant.

Engineering drawings are entirely different from all others. Originally hand-sketched from the practical imaginations of the brain, they next pass into those of the preliminary small scale plan for approval form, and then into the rigidly exact Tee square and scale produced plans, sections, and elevations, which enable the workmen to execute the pattern making, casting, forging, and machining, etc., of the multitudinous details of, it may be, an ocean racer, or a colossal two mile bridge of various spans. It may further be observed that not one detail of any kind can be made in the shops until the workmen have the tracing for it.

The foundation upon which all these performances rest is, firstly, the discovery of what a person or a company who employs you exactly wants; and, secondly, a thorough knowledge of how best and most economically to carry out their wishes. These movements frequently require the most profound practical and scientific experience in design and construction, and a masterly acquaintance with the most accurate methods of finding the direction and intensity of the strains caused by statical and dynamical loads. Besides all these, a knowledge of the experimental strength of materials is necessary to enable the designer to so proportion the details of his structures that they will not only work to

perfection, but require the least amount of expenditure to maintain in good working order.

In marine engineering many of the plans named may be of the most complicated nature, and, apart altogether from their proportioning, there is the vigilance necessarily employed to prevent one detail from fouling another, especially when the space in which they are to work is extremely cramped, as it often is.

Lastly, there is the dimensioning of every part fully and accurately to avoid originating errors in the shops, which, at the outset, can be so easily avoided.

With, however, all the skill, and foresight, and experience that able engineers can exercise in the preparation of working drawings, mistakes are sometimes made, but these are very rarely worked to, as the outside inspection they undergo generally exposes them. Nevertheless, serious errors have occasionally been carried through to the end, three or four of which in a lifetime, I well remember, in various works, and yet, so simple were they of detection in reality, that the wonder still is that the accomplished hands who made them failed to discover them.

Besides these mistakes of the pen or the pencil, there are those termed "Errors of Judgment," two of which now rise to view. Both were made by famous engineers, of very extensive and most successful practice in days gone by, one of which cost fully £100,000 to rectify, and prematurely blighted the life of the responsible person. The other was not only very costly but

involved the loss of many lives, and destroyed the happiness and blasted the prospects of its originator.

Strange to say, a studious apprentice in a neighbouring engineering establishment — who afterwards "reached the top" — made independent calculations concerning the former for his own satisfaction, and found out the error. Armed with a letter from the head of his firm he reported his discovery to the "Eminent Engineer" whom it so closely affected, but, alas! it was too late! the long looked for opening event was to take place on the morrow, the painful result being chronicled in history. Similar disasters, though of lesser degree, have occasionally happened, only, however, to show that the paths, even of great engineers, are not always happy ones.

These remarks, it is hoped, may illustrate the importance of obtaining information which, especially in private practice, one may be unexpectedly called upon to utilise in untried forms. Having done this, I may now proceed with other themes.

The difference between the engineer who to-day begins in consulting practice, and the similar individual of forty or fifty years ago, is very great indeed. In those good old days an experienced professional had work showered upon him. One day he might be asked to work out in practical form special machinery from the most barbarous sketches of an enthusiastic inventor, and, perhaps two days later, have to design a handsome

road-bridge. Soon afterwards would come a subpœna to attend Court, and give scientific evidence regarding the fall of a roof, or the bursting of a boiler, or something else of greater or lesser importance. Whilst waiting for his case to come on, he would be invited to value, as a "going concern," the machinery of some large factory, or mill, or working plant at a quarry. In addition to these high marks of appreciation, clients would be calling from time to time to ask his opinion upon various subjects, or to see if he would kindly undertake the preparation of parliamentary plans for a proposed railway, etc.

All these might so come with a rush as to drive him nearly out of his wits. Good draughtsmen, however, aided by his hand sketches and instructions, would tide him over his various machinery and bridge designs, while he himself gave his whole attention to more personal matters. In this way, many of our old and lately departed "Eminents" were thrust into fame, and honour, and glory, and riches, the three first named being, in some cases, sufficient to girdle the earth and stretch from pole to pole.

When office work is not harassing through outside pressure, an engineer can sleep as well and as soundly as those gentlemen the great Cæsar liked to have about him. There are occasions, however, when he is called upon to design something of a perplexing nature as rapidly as possible. No time must therefore be lost, and all the resources of past experience have to be

suddenly utilized to tide him over the difficulty. For this reason he has sometimes to make the drawings himself to save time, instead of instructing assistants to do so, which thus entails very exacting employment. If, however, it is persistently continued throughout the evening, and into the small sized hours of the morning, the mind becomes somewhat strained, and upon going to bed in the early dawn the engineer may unconsciously take his work with him. Such, indeed, has been my own experience when unduly pressed.

For example, after going to bed with the intention of sleeping, I have had a rough night, or *morning* of it, having been engaged all through the state of somnolence in making calculations and drawing plans. The worst of it was, that the cantankerously unmanageable things never would come right, and, no matter what I did, every effort failed. Calculations would persist in being wrong, colours would not go on a drawing properly, and nothing I could think of was either feasible or workable. There was always something missing that had to be found, something incorrect, something unattainable, and I was glad enough to find on awaking that it had all been a dream. Such experiences have been the lot of many, and have even led to tragic results.

They must have come of a sturdy race, those grand old engineers of the past, to have stood the unceasing wear and tear of mind and body, with the midnight oil burning until morning light appeared, and sometimes

not in bed at all for days. As the profession became better known and systematically organised, and multitudes were attracted to it, private practice began to deteriorate. Instead of going to consulting engineers with their works, Railway Companies, Steamship, Dock and Harbour Companies, City and Town Corporations, etc., engaged these gentlemen for their own special use as Engineers-in-Chief, paid them well, and freely gave them a suitable staff of draughtsmen and clerks.

This system, unhappily, played such havoc with private people, that their practice went down, down, down, until it became what it is to day, in most cases, a mere shadow of its former self. It may be added that the profession has now become so densely overcrowded, that if all those over fifty years of age retired from it, there would be more hope for those who remained. Versatility of mind, and adaptability of thought to anything that came in my way, proved, however, a valuable safeguard from these evils, and happily kept *me* afloat, whilst some of my good and clever brethren could hardly accomplish even this.

CHAPTER XIV.

MY VARIED EXPERIENCES IN PRIVATE PRACTICE.

A Splendid Undertaking in Prospect—Necessary Preparations—Results—Premiumed Pupils arrive—Valuations of Machinery—Their Leading Features—Scientific Evidence in Law Courts—"Vibration" Cases—Their Peculiar Treatment—Compensation offered and Lost—An Iron Work Enterprise—Varieties of Clients—Mr. O'Brien's Character—Wrongful dismissal from the Works—His Law case—An enthusiastic "Invintor"—Duties of a Scientific Witness—Inspection of the Works—"New and Improved" Patent Machinery—Collecting Information—The Bones of one of O'Brien's Pets—Three Lines of Argument in a Report—High Court of Justice, London—Opening the Case—O'Brien in the Witness Box—"Justness of his Cause"—An opposing Q.C.—His exasperating Reticence—Impoverished Plaintiff—A *really* Splendid Invention—Practically Tested—How it Failed—Legal Practitioners as I have found them.

AFTER finishing the working drawings with which I began my career, as mentioned in the last chapter, various other designing practice came to me. I also obtained my first premiumed pupil, and soon afterwards stood upon the verge of one of those "big orders" which Mr. Fairbairn used to delight in.

At this point, Mr. Henry Turner, the late highly accomplished manager of the Thames Iron Works, London, suggested to me that I might act as joint designer with him of a set of large marine engines for

which he had the prospect of obtaining an order from a foreign Government. I replied that I would be very happy to do so. Here, then, was an undertaking, suddenly sprung upon me, of colossal magnitude for a private office, and one which, for some time to come, would fascinatingly occupy my most painstaking thoughts by day and by night, sleeping and waking, everywhere I went.

Well, in view of this expected and splendid occupation, I put my office in order, and placed all the aids I possessed conveniently at hand for immediate use, and stood "waiting for the answer." In a few days afterwards Mr. Turner regretfully informed me that, as the foreign Government had made up their minds to design these engines for themselves, we would have to let them go. Since then the designing of marine engines, boilers, and all their accessories and attachments has been given almost entirely to the *constructive* firms, because, in their very extensive practice, they may have built engines of a similar kind, though not exactly of the same size. Hence, between a large number of drawings already made for other machinery, which may not require much alteration, and also a large staff of assistants already on the spot to carry the work through, it will be seen that rapidity of execution, otherwise unattainable, is ensured.

As time rolled on I came in for many premiumed pupils, some of whom so interestingly availed themselves of my instructions as to subsequently obtain good appointments in various parts of the world. Others did

not do so well, as they were not fitted for such an elaborate profession.

I came in, too, for *Valuations of Machinery* and plant in works of different kinds, which required very careful consideration in detail before one could arrive at a fair estimate, allowing for mechanical depreciation and renewals, and also for output depreciation when compared with later and more useful machinery of the same description. These valuations were chiefly of the "going concern" order, some of which paid well and brought me other cases. Strange as it may seem, however, the valuation of a small work, for, perhaps, a change of owners, pays much better in proportion to its size than some others of much greater magnitude, because there are generally so many small things to estimate separately which require much time and trouble. In large establishments, however, everything is on a grand scale, as they sometimes contain immense quantities of costly machines, massive driving engines, with their boilers, shafting, pulleys, belting, connections, etc.; foundations and fixings of everything; cranes of all kinds, and all movable articles lying about the floors of the various shops in their thousand and one different forms, which may unitedly bring up a valuation to a very large amount.

On one occasion, for example, a well-known architect in Liverpool requested me to value the machinery of a large engineering work in the country, while he himself valued the buildings and land. My part was,

naturally, very intricate; nevertheless, my own total of £53,000, and that of my colleague, amounting to fully £100,000, not only pleased the Company, but, even at a moderate percentage, paid us well, and brought us a re-valuation of the same premises some years later for a new firm.

Another occupation which sometimes enters into the life of the accomplished engineer is that of giving *Scientific evidence in Law Courts*, either with the object of explaining the cause of accidents, or for mere equity cases, etc. Two of the latter, in which adjacent houses were concerned, now come to mind. The Liverpool Corporation had planted their first electric-power-house close up to the back of a small street of poor residences, two of the tenants of which complained of the "very objectionable vibration" thus created. Number three was used as a boarding house for emigrants, who arrived during the night and needed sleep after travel, which the "rattling of the crockery" and the "tremor of the building" prevented them from having.

So great had these evils proved that the wife of number three became "ill," and had to go out of town to recruit, which, indeed, was the head and front of the Corporation's offending. Well, we were all subpœnaed in the usual way for plaintiffs and defendants—two engineers, two architects, and two experts in the beer trade, who were expected to make a full confession regarding the state of the beer in the cellar, which was

said to have deteriorated in quality "all along o' the vibration."

We began by very carefully inspecting every room in the house from floor to ceiling. We placed our ears against the walls, and thus not only heard distinctly the dull rhythmical pulsations of the adjacent engines, but also a mild rattling of the crockery. We visited the engine room and found the machinery in the most splendid order, and running to absolute perfection, as the famous firm who made it intended it should do.

We next tried a very sensitive test by putting basins of water on each floor, so that, by going down on our knees, we could note the rippling which the slightest vibration is sure to set up. The taste of the beer was emphatically noted, indeed, everything was noted which could enable us to clearly understand the case in all its bearings. We then, in our offices, wrote out our true and faithful reports for our solicitors to give to counsel. On the appointed day we all attended the Civil Court in St. George's Hall, and gave our evidence to the best of our judgment. The master of the house declared that the noise and vibration created by the engines during the night were very bad, but that at the time we inspected his premises they were purposely slowed down.

The Judge then said that he would go down unawares and see the engines for himself. Next day, however, some one was wicked enough to tell me that no sooner had his Lordship uttered these words, than a

man in the Court rushed to the power-house to *prepare* them in time for his visit. Compensation to the amount of £600 was offered to our client, but, as he claimed much more, he eventually lost his case.

In a few days afterwards, the man in number five brought a similar action against the Corporation, and therefore the whole strength of the company which defended his neighbour was re-engaged. We again did our parts well, and eventually received our fees in both cases, which, indeed, does not always happen when the loser has no money to meet all his costs. Hence, "eminents" in London will sometimes not only claim a handsome preliminary payment, but decline to act until they get it.

An Iron Work Enterprise.

In the course of many years' practice, an engineer experiences an immensely varied amount of work, and, perhaps, an equally diversified set of clients, which certainly increases his knowledge of the world, but not always in the most pleasant manner.

One of my most notable clients was a lively, quick-witted, impulsive Irishman, from Dublin city; one of those people with fertile brains who are always inventing something or other, but out of which they cannot make any money. Amongst his numerous innovations was a machine for producing "perpetual motion." The whole scheme was joyously described to me, and, to all appearance, its inventor was theoretically correct in his

ideas. Unfortunately, however, Force of Gravity, Laws of Friction, and Atmospheric Resistance so relentlessly opposed him, that he was at last compelled to give his attention to something more practicable, such, for instance, as the economical manufacture of iron.

One of my friend's peculiarities was a great love of lawsuits, especially with the nobility, which, curiously enough, somewhat inpoverished him, and his last "case" was an action he brought against the Duke of Woolloomoolloo, which he lost, in the usual way.

Now this Mr. O'Brien—let us call him—was a rollicky, smiling, brimful-of-merriment sort of individual, and was vain enough to say that I never laughed except when *he* came to see me. Indeed, his description of the way in which he got his wife would have given intense enjoyment even to the most melancholy people, and the references he made to his "Invintions" were not far in the rear. In addition to this, he was kind hearted and liberal when he had money to be lavish with, which, I may add, was very seldom.

Having thus introduced my client, let me now proceed to narrate the story.

One day he came into my office, and handed me a paper in which I found that I was subpœnaed to attend the High Court of Justice, in London, and appear as a scientific witness on his behalf, before Vice-Chancellor Bacon. He also threw down, in a free, off-hand manner, a preliminary fee of three guineas, which accompanied the document. The cause of this trial was the

dismissal of Mr. O'Brien from an Iron Work containing a quantity of his patent machinery, which was expected to enrich its proprietors, but, although a wealthy Greek in London had actually advanced £20,000 to work the establishment, and placed my friend in it as manager, there was, after two years' labour, no profit of any kind. Mr. O'Brien felt hurt at the treatment he had received, and at once brought an action against his employer for wrongful dismissal, upon the ground of his interference with the management of a system of ironworking which was sure to bring, in the end, "an imminse fortune."

I should be very sorry indeed to give it as my opinion that Mr. O'Brien was a hare-brained schemer, but I must say that no one could have been a more enthusiastic admirer of his own discoveries than he himself was, and this fact alone must have given great confidence to those who trusted him. Before going any farther, however, let me briefly describe the duties of a scientific witness.

As it was in days of yore, so it is now. This gentleman occupies an important position, and one which involves trust, responsibility, and delicacy. *Trust*, because the client looks to him as one who is faithful and true, and quite above being led astray by improper bias or prejudice. He is also expected to favour and protect, in every possible and legitimate way, the interests of his client.

It is a position of *responsibility*, because he is often

the main point of attack and defence, and whatever evidence he gives may either make or mar the interests he represents, involving, it may be, issues of tremendous magnitude, as all those who have read the Manchester Canal investigations will know.

Still more is it a position of *delicacy*, because, however great the witness's knowledge of the case may be, he must be very careful how he uses it, and avoid making damaging statements unconsciously, as Mr. Pickwick did in the Bardell case. He will be exposed to a great many hard questions, which he can answer most confidently, so long as they are in his client's favour, but, at the same time, be reserved on points which are not to his advantage.

Before this can be done, however, the case, in all its bearings, has to be carefully studied — minutely investigated—and plans and calculations made when necessary, to render everything clear to the jury, as well as to the engineer himself. Above all, nothing must be said or written that cannot be sustained in court. If you do anything else, the opposing counsel will be down upon you like a thunderbolt, and your client's case may be grievously weakened, if not lost. On the other hand, with care and skill, you may be able to crush them with your incontrovertible statements, and defeat them all in detail by the irrestible logic of facts, as the early engineers did in Parliamentary railway cases.

My first movement in the matter was to go to the

Works with the late manager, and make a careful survey of the premises, upon which to base my report, which was to be given to our barrister. The machinery was all stopped, and I had therefore to do the best I could under the circumstances. My position was simply this:—

I had been invited to look at a collection of patent machines of the "most improved" type, which I had never seen before, and the action of which I was expected to form a favourable opinion of, from the appearance of the inanimate masses before me, instead of having an opportunity of estimating their merits from the amount and excellence of the work I saw carried out by them. It will therefore be easily seen that I had no satisfactory ground of any kind to stand on.

Mr. O'Brien thought differently, and, as he walked beside me, explaining the action of one machine, and telling me what another piece of mechanism ought to have done, had *he* not been interfered with, naturally enough concluded that I would be quite able to thoroughly understand them. I had therefore to use my wits, that is, I had to gaze at everything inquiringly, peer into every nook and corner about the place, ask any number of questions, ponder carefully over all I saw, and at last endeavour to write so favourable a statement of what I had observed, and also what I thought the machinery was capable of doing, that our case would be successfully carried.

My mind had been on the stretch for some time,

and by degrees I had sketched out in imagination the leading ideas of my report, which I intended to clothe in the usual finished style when I returned to the office. So far, all was well, but I little knew what was in store for me. In the yard outside lay a few disjointed pieces of what had once been a "valuable machine," but were now in a very rusty condition; nevertheless, although its construction and application were very fully explained to me, I was totally unable to conceive what it could have done when in the flesh.

If kind readers wish to understand my feelings at this stage, may I request them to fancy themselves in the British Museum, with a few ribs, etc., of the Megatherium or Mastodon placed in front of them on the floor. Let them still further suppose that they were asked, not only to imagine they saw the living animal before them, but to describe his physical peculiarities, and then I think they will comprehend my state of mind whilst meditating amongst a few of the bones of one of Mr. O'Brien's pets.

I did everything I could to collect as much of the best and most trustworthy information previous to delivering judgment in my report. Before doing this, however, I had three courses open to me. One was to say confidently that the machines were *quite* capable of doing all that their inventor claimed for them, which he fully expected I would say. Another was to declare positively that they were *not* able to do this; while the third consisted in taking the mean,—in striking the

average,—in steering dead between Scylla and Charybdis. The first was utterly impracticable, so I took the intermediate course. My legal document was very brief, for I took good care not to say too much lest I should do mischief, since going through these works was like walking on rotten ice, which gave no safe foothold of any kind.

The wording of the report was somewhat in this style:—"I believed"; "I considered"; "So far as I could see"; "In the absence of direct proof"; "The machinery was, in my opinion"; so on, and such like, to the end.

The day of the trial came on, as every day does, for good or for evil, and I was at my post in the High Court of Justice. An old friend of mine was also engaged as a scientific witness on our side, while on the other side were two "eminents." The defendant, whom we shall call Mr. Petali, had also engaged two of the most celebrated Q.C.s in London to look after *his* interests, and thus, with all the actors in the play in position, the case of the "Darkfield Iron Works Company Limited" was opened in the presence of Vice-Chancellor Bacon by placing Mr. O'Brien in the witness-box.

Never in my life—no, *never*,—have I seen a man who could look so much the picture of injured innocence and humility as this son of the Emerald Isle on that eventful morning. It seemed as if he had neither the heart to kill a fly nor crush a beetle, and yet, when

the time came, he could turn upon his persecutors, and with the most unbounded confidence in the justness of his cause and his "armour of triple steel," defy every one of them. In opening his case, he compared the Greek—who sat close to him—to the "wicked king in the Bible," and during the whole of Mr. O'Brien's lengthy examination those in court had an amusing entertainment freely provided for them, Question after question was asked in the usual "be careful" style, first by one barrister, and then by another—the Vice-Chancellor assisting—but the replies were sometimes of a surprising, if not of a damaging character. One of the interrogations was :—

"How much profit do you think might have been made if you had not been interfered with ?"

"*Millions*," was the prompt and enthusiastic reply.

"When you were there, and with the machinery in good working order, what were the actual returns ?"

"None, but that wasn't my fault, and if I had only had a little more time, and not been interfered with, I would have made the place a success."

In the course of the trial the Greek's perfidy was fully exposed, and irrelevant things connected with his private character were introduced in support of the plaintiff's arguments.

"Read that letter," said the indignant gentleman in the box to the very eminent opposing Q.C. and M.P., who was busily occupied in conning over a large quantity of correspondence relating to the defendant.

"Read that letter you have just skipped over, and see what his brother says about him—read it like a man, and you will see the character he gets."

Part of a barrister's education consists in practising the art of reticence, or keeping silent on points inimical to a client's interests. In time he becomes quite accomplished in the art of hearing what he ought to hear, and in suddenly becoming deaf to statements to which it would be unwise to listen, and such, I think, was the case in this instance. The Q.C. went on reading for the benefit of the judge and jury only what *he* thought proper, and rejected all the rest as irrelevant—he also took not the slightest notice of Mr. O'Brien's proposal.

After attending the court for the whole of two days my turn came at last. I told them what I thought of the machinery, "so far as I could see," "so far as I could judge," etc., etc., and the result was quite satisfactory. Our barrister, whom it was quite a pleasure to meet, did not ask very many questions—for wise reasons, probably. Other witnesses followed, and amongst them was a drawly, slow-speaking Yorkshireman, who had been a gateman at the works. Upon being asked—

"What time did the works close at night?"

"E-eh," he said, "wa-at to-ime?"

"Yes," replied our counsel, in a smart, gentlemanly style, "what time of the *day* did you leave off at night?"

"Wa-al it war abee-out foi-ive o'claw-k."

Mr. O'Brien lost his case, chiefly on commercial

grounds, which no one perhaps, except himself, could possibly have been surprised at. Had our trial, however, been successful, we should all have been generously treated, for the fertile inventor and lover of legal disputation was an honourable and liberal-minded man, and would then have had *more than enough* to enable him to settle all claims in the fullest manner, as I am sure he would have done.

Another of my clients was a man who came from Australia with an invention to which he attached so much importance that he secured the services of the best people to do the legal and patenting part of the business for him in connection with various countries. He also asked me to prepare the working drawings, and superintend the erection of works wherein to test the practical value of the invention.

Mr. Bee was a quiet, pleasant man, who had studied and worked at his subject for several years, and possessed a most exalted idea of its value, which he had so thoroughly impressed upon rich friends as to win their very generous financial aid.

He was frank and straightforward in disposition, and wished everything done in the very best manner, and yet, after the scientific importance of this new system of manufacture had become well-known, it proved an utter failure from a commercial point of view, after many thousands of pounds had been spent upon it, because the new process—most admirable and beautifully simple as it certainly was—could not be worked

economically enough to enable it to compete successfully with a long established and similar manufacture upon different lines. This, however, is a specimen of only one of the serious evils with which even the best inventors have sometimes to contend.

It would be unkind if I did not refer to my good friends the gentlemen of the legal profession, with which I have been closely connected all my life, as many of my own relatives have been in its ranks—as judges, barristers, and as solicitors. Legal practitioners are generally most courteous and humorous, but they never appear more charmingly interesting than when hilariously excited by the replies of a witness such as the aforesaid Mr. O'Brien—by their own extemporaneous witticisms—or when we are honoured with their assistance in solving those knotty points of equity so frequently to be found in our own practice.

Some years ago the designer of a high level bridge scheme tried to explain its peculiarities to one of my good friends, and after a short conversation exclaimed: "It's easily seen that *you* are no engineer."

"Exactly so," said the ever genial and witty lawyer, "exactly so, but to me it is very evident that you are not a *civil* one."

CHAPTER XV.

HOW COMPETITIONS ARE CONDUCTED.

Professional and Non-professional Clients—Hints to Inventors—Architectural and Engineering Schemes—*Eatanswill Bridge Competition* — Town Councillor's Invitation to Engineers — The Opening Day—Arrival of Plans—Character of the Town Councillors—S. J. Drayne, the Borough Surveyor—Alfred Sketchly, the Draughtsman—How they spent their Apprenticeships—Their Private Notebooks—Discussing the Plans—Mr. Drayne's Advice — Mr. Sketchly's Logic — Results — Present System of Competitions—Skill and Labour required in preparing Designs and Estimates—Improved System—Liverpool Cathedral Competition — Iron Pier Competition — How it was Settled—True Value of Skilled Advice.

An engineer's clients may be said to include two great classes—the professional and the non-professional. The former refers chiefly to those who are engaged on some undertaking which belongs partly to one branch of science, and partly to another, such, for example, as railway stations, public buildings, warehouses, etc., in which the architect may require the services of an engineer, or *vice versa*.

In cases of this kind each individual bears his own responsibility, that is, the architect has sole charge of the brick, stone, concrete, and timber portions of the building, while the engineer designs and superintends the erection of all the iron and steel work contained in

it, such as girders, columns, and all other similarly constructive parts. The person responsible to the owners being the individual who undertakes the work as a *whole*. Under these circumstances a large contract may be executed in the most felicitous manner, because the two principals thoroughly understand their duties, and act in concert with each other.

This state of affairs is entirely changed when a capricious non-professional engages the services of a C.E. to assist him with a new and perplexing scheme. In private practice instances of this kind are by no means uncommon, as an engineer is sometimes called upon to work out the hazily conceived and imperfectly described ideas of a client whose perceptions are visionary, if not unpractical, and who, therefore, causes a great deal of trouble and considerable loss of time while endeavouring to obtain what he desires. One of these clients I well remember; let me call him Mr. John Smith—a well-known name.

For some time previous to our acquaintance this gentleman had gradually matured an idea in reference to tramways, a miniature model of which had been made with the object of illustrating its beautiful simplicity. Unfortunately, however, by the aid of working drawings, the scheme was found impracticable on account of the great difference which existed between a real tramway and a model tramway. We, therefore, tried another system, and in this we eventually succeeded.

Mr. Smith was a most enthusiastic inventor, and fancied he had discovered something that would pay much better than Trade and Commerce, with which he had long been intimately associated. Almost every day he came to my office with his mind filled with "grand ideas" he had conceived the night before, which completely neutralised all our previous labour. I gave him the best advice in my power, but he preferred having his own way, as he had thought of his invention by night and by day, had cogitated and ruminated on it, and slept over it, and dreamed over it, and—I had not.

The continuous alterations of the drawings was of no consequence to him, and what he did in this respect was accomplished in such a slap, dash, bang! sort of style as to give one the impression that he was going to make a fortune by his discovery, and that it would be a good thing for everyone connected with it. At last we succeeded in designing a very simple and perfect arrangement, and a Tramway Company gave him permission to lay down his improved apparatus at two or three points on their line. He did so, to their entire satisfaction, but beyond this initiatory movement nothing else was ever accomplished, although a favourable offer was made for the purchase of the invention, which, however, was declined, as Mr. Smith expected much more.

I have, here and elsewhere, given a few of my own experiences of inventors and inventions, for the benefit of readers to whom such information may be useful, and

may only add that the point at which so many worthy people of this class fail, is the limited sweep of their views regarding the adaptability of their invention to some particular purpose for which there is likely to be a demand, prosperity or misfortune chiefly depending upon the clearness of these views.

How "Competitions" are Conducted.

There is no class of work in which engineers, as well as architects, have been so grievously abused, as that known by the term "Competitions." With many architects, the preparation of competitive sets of drawings necessarily occupies a large amount of their early and unremunerative practice. So also is it sometimes the case with engineers. The true object of a competition is to obtain from as many able professionals as possible a set of plans, estimates, etc., expressing their matured ideas in reference to a bridge, railway station, promenade pier, or, indeed, anything else that has to be built on the most approved principles. When all these plans have been prepared, they are sent to the secretary, or other official of the Company, etc., who invited them.

At the next meeting of the Board of Directors, these plans, specifications, and estimates are carefully looked into, and their merits balanced. Plenty of time is taken to consider the matter, and at last the prizes are awarded to the successful competitors, the gentleman first on the list being requested to carry out the

work. Now this is as it should be; but is it always so? In too many instances, "this is how it is done"—as Dr. Lynn, the conjurer, used to say.

Suppose, for example, that a handsome road bridge has to be erected across the river Muddle, which cuts the town of Eatanswill in two, and is required to supersede the old wooden structure which has been used for very many years. The first thing to be done is to obtain the consent of Lord Portansherry, who will, no doubt, graciously sanction the scheme because he thinks it will do himself good as well as the townspeople.

A meeting of the Town Councillors is now held to consider the matter. One gentleman proposes a stone bridge, as there is an excellent quarry close at hand which belongs to him. Another, who is a timber merchant, thinks they ought to have an improved type of trestle bridge, because it will cost so little; and, lastly, one of the "committee," who had six months' jobbing in a small foundry, advises them to make it of iron, and "he will see that it is well done."

As the latter is allowed to be quite an authority in the metal trade, it is definitely settled that the new structure shall be as he suggests. And, since their own low salaried borough engineer is too inexperienced to design the proposed bridge on his own responsibility, it is also decided to "invite" engineers to send in competitive sets of drawings, with specifications and estimates, by a certain date. The invitation reads as follows:—

BOROUGH OF EATANSWILL.—PROPOSED NEW BRIDGE.

The Town Council of the Borough of Eatanswill, acting as Urban Sanitary Authority, INVITE COMPETITIVE DESIGNS and ESTIMATES for the CONSTRUCTION and ERECTION of a WROUGHT IRON BRIDGE over the River Muddle, with the necessary foundations, piers, abutments, and approaches.

The Bridge is to be 200 feet long, by 35 feet wide, and adapted to carry a moving load of 20 tons.

A plan and sections of the proposed site and approaches, with other particulars, can be obtained on application to Mr. Streeter J. Drayne, Surveyor to the Council, Town Hall, Eatanswill, to whom all estimates and designs, under seal, must be sent on or before the first day of June.

The Author whose Designs and Estimates, in the opinion of the Council, shall be considered best suited to their requirements, will be awarded a premium of £25, unless he be appointed at the usual commission to carry out the Works.

By order,

E. VERNON QUILLE,

Clerk to the said Council.

Eatanswill, 1st May, 1905.

Let us suppose that the opening day has arrived. Thirty sets of plans having come in, a second meeting of the committee is held for the purpose of examining the drawings and considering their merits. The members now assembled are all good and true, and also accomplished men; that is to say good at selling spirits, groceries, meat, etc.,—true to their own interests,—and accomplished in the art of colouring their statements to

suit their own ideas. Not one of them knows anything about bridges but the ironfounder, and his information is so superficial as to be practically of little value. Another feature they possess is, that actions which each individually would consider dishonourable are thought quite excusable when taken collectively.

We shall now imagine them all sitting around a table in the committee-room, with the plans exposed to view on the walls, and, with Mr. Drayne, the borough surveyor, on one side, and Mr. Sketchly, his draughtsman, on the other side of the chairman, they are ready to begin operations. Before going further, however, let us say a few words concerning the two professionals, whose services will be of a very important character.

Mr. Drayne served his apprenticeship in a builder's office in London, and acted as draughtsman for some years to the borough surveyor of a small town. He was one of those inquisitive people who are profoundly impressed with the idea that the surest road to success is by picking up all the professional knowledge they can, and in utilising every kind of information that comes within their reach, and may possibly be useful to them at some time or other. The result of this line of action in days gone by is, that Streeter J. Drayne, Esquire, is now installed in his present position, and, although the salary is not much, the experience gained while thus employed will prepare him for a more lucrative appointment in course of time, which, indeed, he is now aiming at.

If you had a peep into his private note-books, you would find all sorts of memoranda and tables, compiled from a great variety of sources, and having special reference to hydraulic calculations of various kinds; useful particulars concerning gas and water works, and also sanitary engineering in general; notes of experiments upon the strength of brickwork, cement, mortar, timber, and an immense quantity of general information which he now finds most useful.

Mr. Sketchly, on the other hand, was a pupil of Fairbairn's for five years in the works and drawing office. He was a lively, happy youth, and one of the most diligent students that ever entered the famous Canal Street establishment. The great engineer no doubt knew pretty well what to expect from the sons of the nobility and rich gentry whom he received from time to time. In other words, he had a good idea that many of them would make engineering a sort of fashionable amusement, and leave him with little more practical knowledge of his splendid productions than when they began their apprenticeship.

With Mr. Sketchly, however, the case was very different. He, too, was connected with the "upper ten," but owing to the death of his father, who had been a barrister, it was advisable that he should bend his whole energies to whatever pursuit in life he entered upon. Nothing escaped his notice, either of an inside or of an outside character, relating to the daily practice in the works, and, however idle and vapid the other

apprentices might have been, there was one, at least, amongst them who went in and came out with the intention of using every effort, and watching every chance of obtaining information which would enable him, when future opportunities arose, to reach the top.

If Mr. Sketchly had allowed you to look into *his* private note books, you would have seen a large number of very neat sketches of engine, boiler, bridge, and general engineering details of executed work, carefully lettered in reference to accompanying tables of proportions. You would also observe a great quantity of simple formulæ and memoranda of all kinds, derived from the very best sources. Such books, he would tell you, were absolutely invaluable to him, on account of the saving of time and the confidence they inspired when designing work, and forming, as they always do, a most efficient check upon the untrustworthy deductions of mere theory.

Now it so happened that Mr. Sketchly was an experienced hand in every kind of bridge work, and Mr. Drayne was equally eminent in his own particular sphere. They also acted in concert most harmoniously, and tried to learn as much as possible from each other in view of future changes arising. We may therefore congratulate the Town Council of Eatanswill upon having obtained the services of these able gentlemen.

Having thus introduced to the reader the company now assembled in the committee room, we shall proceed to let the chairman open the meeting.

After gazing quietly for a time at the array of "trellis," "lattice," "arched," and other bridge designs, with which the walls are adorned, that individual makes a few preliminary remarks, and then, turning to Mr. Drayne, observes:—

"Now, what do *you* think of them 'ere drawin's?" pointing at them with his thumb.

"Well, sir," replies the surveyor,—who has been carefully instructed by Mr. Sketchly,—"I have just been looking over them all, and I think that they are a very nice collection of designs, but, in my own opinion, 'Gamma's' piers and abutments are very handsome, but his plan is too expensive. That lattice bridge by 'Alpha' looks remarkably well, but the struts seem rather weak"—"*Ties*," whispers the draughtsman. "As I was observing when Mr. Sketchly interrupted me, the ties seem rather defective in strength. The most suitable of all the designs, however, is 'Delta's,' and if he can build it a little cheaper, I think we ought to adopt it."

A lively discussion now takes place amongst the members of the committee upon the merits of every design, and the three Greeks, with their companions, are fairly on their trial. One leading feature after another is pointed out and commented upon. The spirit dealer greatly admires the colouring and printing of some of the drawings. The greengrocer is charmed with the architectural effect of others, while the cost of all is fully considered. Some are in favour of one thing

and some of another, but on those points which are really of the highest importance, none will agree.

Mr. Sketchly is the only person who knows anything at all on the subject, and able to give a good opinion, but as he is "only a draughtsman," his advice is not asked for. This gentleman takes good care, however, to show his talent by talking so freely about the technicalities of bridge construction that not a single member can follow him, although they are at the same time, astonished at his "cleverness." And if any of them objected to his style of reasoning, the "draughtsman" crushed them at once by observing, "*That is the way we used to do it in Fairbairn's.*"

Owing to the extremely conflicting opinions of the committee, the ironfounder proposes that a new set of plans should be made, embodying all their matured ideas, and, as this proposition is unanimously carried, the chairman orders Mr. Drayne to "pick out all the best p'ints of them 'ere drawin's, and arrange our improvements as you think best—Do you 'ear?"

"Yes, sir."

The plans are now handed over to Mr. Sketchly, who does the rest. Estimates are again requested in accordance with *his* specification and drawings, and eventually a handsome bridge is erected, which Lord Portansherry has the pleasure of opening. The rejected designs, etc., are returned to their owners, after a few of them have been noted in some way or other, with the object of facilitating the compilation of the "new and

improved arrangement," and the successful competitor receives his £25.

This gentleman, who should have had the work to carry out, is grievously disappointed, and all the others, who expected, at least, fair treatment, discover that their labour has been in vain, because there was no one on the Board who knew how to appreciate a good design when he saw it. For the paltry sum of £25 the councillors obtained a large amount of valuable information from a variety of sources, and perhaps the only legitimate advantage derived from the whole transaction was the knowledge thus conveyed to the numerous competitors regarding the treatment they might expect in future if rash enough to engage in similar work.

This subject was fully discussed at a conference of architects held some time ago in Manchester, on "Professional Practice."

The Chairman remarked that—

> Competitions, as at present conducted, are becoming the very curse of the profession. The gross acts of injustice which are being constantly brought before us show clearly that some action must ere long be taken to remedy such a crying evil. Properly managed, they may be of use to many, and afford numerous opportunities for the display of ability, but such is seldom the case now. It is not the best design, as a rule, that is chosen, but one whose author has most friends. Very often he is practically selected before the competition is invited, and, after his selection he is allowed to adopt

ideas taken from the real competitors' plans. . . . . Fifteen hundred architects have pledged themselves not to enter into open competition, unless a professional arbitrator is appointed, but this alone is not a sufficient remedy.

Referring to estimates and contracts, this gentleman also stated that—

It is well known to architects that the lowest estimate often means something less than cost price, and also faith in the chapter of accidents, such as alterations and additions, or scamping the work so as to obtain a fair profit.

I hope none of my readers will imagine that the sketch of the "Eatanswill Bridge Competition" refers to similar undertakings in general. Nothing could be further from my intention. In the great cities things are done much more genteelly, but, in too many instances, the results, from various causes, have been very disappointing.

We may, however, in common justice, try to believe that the state of things described is sometimes caused by the ignorance of people regarding the amount of skill, and time, and labour required for engineering plans. A good design for a bridge, great roof, waterworks, et cetera, requires most careful, elaborate, and patient investigation of all the features of the case before the engineer can fairly realize what has to be done, and how it is most cheaply to be accomplished. In the next place, all the proportions, strengths, and

arrangements of the various parts have to be calculated and sketched out roughly, for transference to the drawings as they proceed. This portion of the work requires great exactness because the specification, quantities, estimate, and expected success of the scheme, are entirely dependent upon it.

For the same reason, also, the specification must be a complete document in every sense of the word. The quantities of materials are not often written out officially for a competition, but the engineer must nevertheless know, for his own satisfaction, what they amount to, before any correct estimate of cost can be arrived at.

We may add that the architects have caused an improved system to be introduced, which is as follows:—

When competitive designs are required for a building, and, in accordance with clearly defined conditions, anyone who pleases may compete, all, however, that is necessary to be done, is to send in sufficiently illustrative sketch plans to a small scale. These preliminary designs are now examined by competent persons, who select, say, about six of the best, the authors of which are requested to re-arrange in a large and more complete form, with full specifications and estimates, and deliver them to the secretary of the Company for whom the work is intended.

The plans are now carefully scrutinised by leading professionals, and one feature is intelligently compared with another, until a fair and impartial opinion is formed concerning their respective merits.

When this is accomplished, the owner of the design most approved of is advised to proceed with the details of the undertaking, until it is completed, while the five rejected competitors will each receive perhaps from £100 to £300 or so for their trouble. The original sketch plan people, on the other hand, however, have no remuneration given them, but this they fully understood from the beginning. This, I may add, has been the system adopted with regard to the Liverpool Cathedral, and many other recent edifices.

It is my usual practice, when obliged to speak or write on disagreeable subjects, to throw in, somehow or other, a scintilla of light—a ray of sunshine—and, if possible, a spark of humour. I have therefore much pleasure in closing my remarks upon such an unhappy theme as "Competitions," as they were, with a felicitous experience of my own.

Some time ago a firm of architects invited me to perform my share of the work in connection with an iron pile pier for which they were trying. This pier was in numerous fifty-feet lengths of lattice girders, supported on cast iron columns or "piles." The land approaches were in masonry and concrete, and at the extreme outer end was a fine bowstring bridge of 140 feet span, leading down to a landing stage. Well, we sent in very clear and nicely finished drawings, which so pleased the "Commissioners" that they favoured us with the whole of the work to carry out in accordance with our own ideas.

We had a little pardonable triumph over this business, because another plan might *really* have been better, but our drawings were so explicit, so beautifully coloured, and so admirably printed and figured, that the judges no doubt understood them easily, and were, in consequence, much gratified with themselves.

After two years of successful working, the Eatanswill bridge mysteriously fell into the river, to the great astonishment of the Town Council, the cause of this disaster being a weak point in the structure which had escaped the notice of Mr. Drayne.

Mr. Sketchly was certainly an admirable general draughtsman and engineer, but his experience in bridge building was, in this case, neutralised by the unwise interference of the responsible chief. The Borough Surveyor was, as we have shown, quite ignorant on this subject, and his principals were utterly incapable of appreciating the value of professional talent in the economical design of costly structures. Or, indeed, of realising the disastrous consequences which may arise when a brick and mortar surveyor occupies the post of Engineer-in-Chief in such cases.

In course of time another bridge was built, upon improved lines, under better management, and with, at last, permanently successful results.

CHAPTER XVI.

DRAWING OFFICE PRACTICE.

Preliminaries of Contract for Naval Ships—For Merchant Ships—Conference between Shipowner, Builder and Engineer—The Shipowner's ideas of *Steam Turbine Engines*—Opinions of the Engineer—Three Ships to build—The Accepted Estimate—*Not* the lowest—Contract settled—Work commenced—The Drawing Office—How it sets the Works in motion—Three sets of Engines to design—Preliminary movements—Application of Practical and Theoretical Science—Good and Bad Engineering — Their Results — Three distinct Classes of Designers — *The Chief Draughtsman* — His Attainments and Responsibilities—System in preparation of Working Drawings—Sources of Error—Swell Draughtsman from Maudslay's ?—"Urgent" Plans of Machinery — How we carried them through—*Art* in Engineering Drawings—How to keep one's self young and hearty in Professional Life.

IN the descriptions of Works on the Clyde and Mersey already given, I have referred to the principals and the manager,—mentioned the peculiarities of some in the drawing office,—explained the duties of foremen and workmen, and made some remarks upon the apprentice question. In all cases I have given my own experience of them during many years' practice in their midst, and now propose to give a rough sketch of the operations usually adopted in the designing of marine engines. Whilst attempting to do this, however, it is not

necessary to refer to any particular establishment, because first-class firms generally do not vary much in their system of management.

Let us suppose, for example, that a shipowning firm wish a few additional vessels built for a particular service, and with a certain speed, cargo and passenger capacity, draught of water, and so on. This would be right enough for the merchant service, but in the navy "cargo and passenger capacity" are almost unknown.

If the Admiralty desire a Battleship built in a private yard, and in accordance with the latest and most improved principles, they will either submit their own plans and specifications to people from whom they invite estimates, or they may give only a few leading particulars of ship and engines, and leave certain favoured firms to design, in a sketchy style, what *they* consider the best arrangement, reserving to themselves, however, the right of judgment in such matters, and also the selection of the most suitable firm to whom to give the contract.

In the merchant service this last-named system is frequently employed in a greater or lesser degree; but at other times the shipowner, through his consulting engineer, designs his own ships, and then requests builders, etc., to estimate for their construction in accordance with these plans, and also a specification, which is a long and very carefully written document, giving in detail the leading proportions, quality of material, workmanship, etc., in reference to the required

work, full liberty being given to engineers to adopt their own methods of executing these details.

It may so happen, however, that a Company has had a number of successful vessels built and engined on suitable terms, and with the least trouble to themselves, by firms in which they have every confidence, such as, for example, in olden times, the Peninsular and Oriental Company and Tod & Macgregor; also the Cunard Company and Napier; and at the present, the White Star Company and Harland & Wolff. Now, if a steamship owner, even at the present day, wishes to act in a similar manner, he will arrange with the builders all that may be necessary regarding the new ships, and in furtherance of his views will pay them a visit, when he will be most cordially received by the principal partner and the engineering manager, both of whom will, very likely, conduct the interview in the following manner :—

The latter gentleman telephones to the drawing office, "Send at once the general plans of engines numbers 916 and 917." The gentleman who replies now opens a large drawer, containing a great variety of similar plans, and soon finds what he wishes.

"Now," says the manager to his client, spreading out the drawings on a large table, "here are the plans of two fine sets of our own five crank engines we recently built for the *Masulipatam* and *Seringapatam* of the O. & P. Company, which worked remarkably well upon less than one pound of coal per horse power per hour, and indicated about 10,000 horse power."

"Very admirable arrangements indeed," replies the shipowner, "and as those of the same type you have already supplied us with have been most economical, I think you may well make similar machinery for our new vessels, but of greater power."

A lively discussion now takes place upon the relative merits of "long strokes," "rates of expansion," "very high-pressure steam," "simple arrangements,"—so on and so forth—which the two able scientists explain so fully and so clearly that the client feels he is in the presence of people who know *everything*.

Before separating, a few remarks are made upon the latest improvements in marine machinery. "Parsons' people," observes the shipowner, "have done splendidly with the turbine engine, so also have Denny, but for my own part, I am very slow in adopting new ideas in machinery when old ones do so well." To which the managing engineer replies that he "expects a great future for the turbine at sea, but that nothing can excel, from every point of view, the engines shown in the drawings before them."

During this interview, three talented people have discussed in the happiest manner, and with the greatest intelligence and ease, a scheme which involves an outlay of hundreds of thousands of pounds. They have all been perfectly above saying anything that was not absolutely correct, and free from that colouring which inferior persons so often adopt, but they are, nevertheless, masters of the art of "putting things," and also of

clothing their ideas in expressive and elegant language. In short, this conference has enabled them to explain all that was necessary, and the only thing that now remains is to arrange about the cost of the ships, based upon a few leading particulars.

The above simple and expeditious method of describing a shipowner's requirements is adopted in this case because the builders know exactly, from past experience, what is desired, as they possess full specifications of similar vessels supplied to the same firm, between whom and themselves the greatest confidence exists. Were it otherwise, a carefully prepared specification would have been drawn up by the owner's consulting engineer, lithographed copies of which would have been sent to engineers and shipbuilders who were "invited" to tender for the contract.

In the course of a few days, the steamship owner receives a statement of cost of the proposed addition to his fleet, which is carefully examined and commented upon in his private office. "These people," he observes, "ask a high price for our three ships, and I know I could get a lower estimate elsewhere, but they turn out splendid work, and we shall make up for the extra expenditure by economy in repairs and maintenance." The other partners of the firm express the same opinion, so, without further delay, the contract is handed over to the builders, to proceed with as speedily as possible.

In bridge, roof, and other work, however, of a more regular character, "Quantities of Materials" are added

to the specification, and thus estimates can be given with exactness and less trouble. But however binding this arrangement may be upon both parties, there is always provision made for alterations which may suggest and develop themselves as the work proceeds, involving, it may be, an increase or perhaps a reduction in the cost, and this is clearly understood by those who give the order, as well as by the people who execute it.

THE DRAWING OFFICE.

In good establishments, the drawing office is practically the seat of government, as it unlocks the whole of the complicated and extensive machinery of the works, and a great deal that is outside of them as well. In short, all the immense capital that may be provided for carrying out some vast scheme remains idle until set in profitable motion by the scientific staff.

When, therefore, an order is received, such as the one before us, it is at once handed over to the drawing office authorities, who initiate the first movements. The diameters and stroke of the steam cylinders, and pressure of steam, say 270 pounds per square inch, having been already fixed, a preliminary sketch design, to a small scale, consisting of front and side elevations, and also plan, is begun with the object of ascertaining the general arrangement of parts, in which many temporary large scale details are of great assistance.

After finding the size of crank shaft, distance apart of centre lines of engines, and also centres and diameters

of air and circulating pumps, and dimensions of condenser, etc., the working general drawing, in sectional elevations and plan, is commenced, to a scale of at least one inch to one foot, on a sheet of web-paper damp-stretched on a large drawing board, while working drawings of some of the details themselves are put in hand throughout the office.

These are drawn to various scales, according to circumstances, but 1½ inches and 3 inches to one foot, half size, and for small gear, full size, are very generally used. Everything has to be most carefully and patiently worked out with the greatest accuracy and elaboration, and every dimension clearly figured before the draughtsman will allow tracings of any of his drawings to go into the works, and after all this is done, it is surprising how errors will sometimes creep in, in spite of every effort made to avoid them.

These inaccuracies, however, are very seldom worked to, perhaps they flash unbidden into the draughtsman's mind when he is going home, or the manager or chief draughtsman may detect them, but sometimes it is the foremen or workmen who do so.

It is at this point where the highest practical and theoretical skill of the engineer is most required, and where any mistake may easily cause serious results if not discovered in time. Numerous calculations have to be made, verified, and compared with past practice—the "Theory of strains" is fully worked out, so also is the "Strength of materials," and between these two valu-

able branches of science the proper proportions of all the parts is determined, and the work proceeds.

However excellent, from a scientific point of view, these proportions may be, they are all more or less over-ruled by practical considerations—the result of long experience—which generally cause much greater strength to be given to the details than theory alone would indicate. Another most important consideration is "Construction," since upon this depends the economical, or, indeed, possible execution of all the parts, and also the facility in working and repairing the engines at sea.

It is here, too, that the difference between good and bad engineering begins to show itself. Under the former, and with due care and constant vigilance, everything goes on well; the progress in the shops is rapid and satisfactory; patternmakers, founders, turners, fitters, erectors and others all work together, and when the engines and ship are completed and sent to sea, the result is most gratifying to all concerned. This will be fully realised when it is known that while Theory certainly holds the light, Practice does the work with such all-pervading efficiency that so few accidents occur in our sometimes overdriven mail liners, on our over-worked railways, or in any other branch of mechanical engineering one could name.

With bad engineering the case is very different, since at the outset grave errors may creep in which threaten the life of the machinery. Boilers may be too small,

condensing surface insufficient, steam ports and valves improperly proportioned; patterns are made which cause cracked or unsound castings; forgings, and other parts are made of an unnecessarily expensive and unsuitable form; indeed, much may be done unwittingly to bring in the end heavy misfortune, decreased prestige, and loss of clients, several marked examples of which might be given.

This, therefore, is the point where three distinct classes of engineers begin to manifest their powers, namely, those who adhere rigidly to old ideas because long practice has shewn their value, although better and newer systems exist. Those who too quickly adopt the numerous "improvements" which enterprising inventors are so delighted to introduce, and so ready to prove capable of doing *great* things. And, lastly, those who reject the old but well known systems in favour of modern innovations which their own sound judgment highly approves. In other words know how to select what is *really* best from much that only appears so. This, it may be added, is the true reason why marine and other machinery of the present time is so greatly superior to that of earlier years in strength combined with lightness, faultless working, and also in general suitability and economical manufacture. The requirements of engineering drawings, which may represent very many thousand pounds in one order alone, will thus be clearly understood.

The presiding genius of the drawing office is the

head draughtsman, whose duties are perhaps more anxious and harassing than those of any other head of department in the works. Besides possessing high scientific attainments, he must have a thorough knowledge of the possible and impossible, and also the simplest and best systems of construction.

When many orders are in hand, the "chief" has a very busy time, having not only his own special work to do, but also to supervise every drawing and tracing before it is sent to its respective department. The regular draughtsmen have all their own responsibility to bear for any mistakes that may occur through wrong figures or lines, or misinterpretation of plans for want of clearness, or insufficiency of views; and, although the chief draughtsman cannot be expected to check everything, he nevertheless verifies, to some extent, the proportions and arrangements of machinery before plans leave his hands.

A good chief draughtsman in a large marine establishment is accomplished in many ways. He is generally one who has closely and persistently studied everything in his profession—has worked while others played—and, in course of time, has accumulated an immense quantity of rules, tables, memoranda, data, etc., from his own daily practice, and other sources as well. These are invaluable, as they enable him to design and proportion the most important work with facility and confidence, whether for a firm, or on his own account for a future time.

The style in which drawings are prepared is of the highest importance. Before a drawing can be properly understood, the piece of machinery it represents must be clearly and fully shewn in a sufficient number of views, and if any one of these is left out through a wish to economise time, the detail is likely to be made wrong, as many engineers have known to their sorrow. Another source of error and trouble is sending out tracings carelessly or insufficiently dimensioned, under the belief that the workmen can measure them with their foot-rules. This, we need hardly say, is a vicious practice, and entails mischief and loss in various ways.

In good establishments generally, every working drawing, large and small, is so fully and carefully figured, that no one need at any time apply a rule or scale to it. In this way the work is greatly facilitated, and the risk of error reduced to a minimum. Besides this, everyone in the office knows exactly how things have been made when referred to in future, and should any departure from the original become necessary, the plan is altered, even to the smallest bolt holes, in red lines—to shew the distinction—before anything can be done with it in the shops. Indeed, a set of drawings should be so complete, so accurate, so expressive, that when all the details have been made and machined to them, they ought to come together with the least amount of hand-fitting.

In olden times they seldom troubled themselves

about office alterations. If the manager saw anything outside which he could possibly improve, he simply said to the foreman, "Make that a little thicker," or "I wouldn't put quite so much metal there," the diameter and pitch of bolts, etc., being similarly treated, no notice being taken of the drawings.

The modern system, just described, is in every respect most admirable, although costly; but the saving of labour and time, and loss from various causes in the works, combined with easy adaptation of the drawings to similar engines and boilers in future, is a sufficient recommendation.

I am here reminded of a gentleman who came to Laird's in my time. He was a handsome man, of about thirty-five, and was formally introduced to us all by our chief. We bowed, smiled, and said pleasant things, and fancied our new comrade was a swell from Penn's or Maudslay's, but when he made a start he seemed to know so little, even of a rudimentary nature, that we could only conclude that our accomplished Mr. B—— must have known him long before as a gentleman apprentice with means, one of those festive youths who can spend five years in a first-class establishment without learning anything useful—and that he had at last taken up engineering to make a living, which, in a few days, he had to try for elsewhere.

The various systems adopted in the preparation of engineering drawings above mentioned have reference chiefly to first-class firms, but there are some who seem

to imagine that, so long as they turn out good work in the shops, the plans may, from an *art* point of view, be executed in any sloppy, off-hand style. There are others, however, who think differently, and we commend them for it, especially when there are so many people in the world who reason like John Russell's sailor. John was a fellow apprentice of mine at Denny's, and had been several voyages before the mast. Amongst the various stories he used to tell us was one about a coloured sailor on board his ship, who always exclaimed when he saw anyone do something difficult, "Well! well!! well!!!—de man dat could do dat ting could make a *chronometer!*"

It may be well to add that the term "picture drawing" indicates something very different indeed from what has been referred to. Plans of this description, especially by private practitioners, are of the *high art* species, and, while intended to give non-professionals a clear and general idea of proposed arrangements of machinery, they are, at the same time, expected to attract their admiration and attention by means of admirable lining, beautiful flat tint colouring, and neat figuring and printing.

As I have already referred to Mr. W. F. Stanley's drawing instruments, as I have known them for half a life time, it would be well here to note his admirable books—*Mathematical Drawing Instruments*, price 5s.; and *Surveying and Levelling Instruments, Theoretically and Practically Described*, price 7s. 6d. The former is

especially useful to mechanical engineers, and both to other engineers and surveyors.

Although we were seldom pushed with our drawings in the Birkenhead Iron Works, when necessity demanded it, we made a grand dash to get finished in time. Some, however, of our greatest efforts were spent over Admiralty orders in prospect.

On one occasion we had a tracing of a large plan of machinery to prepare for an ironclad in great haste. It was big enough to let a draughtsman into each of its four corners, and away we drove at it as merrily and heartily as we possibly could. The lines and circles grew rapidly, and when they had all been put in, we turned the tracing upside down, pinned it tightly round the edges, and laid on the colours in light flat tints of prussian blue for wrought iron, neutral tint for cast iron, crimson lake for copper, yellow ochre for brass, and darkened all apertures, such as the furnaces of boilers, with washes of Indian ink. After the finishing touches had been put in, the plan had a very handsome appearance, and no doubt created the desired impression.

It may be added, that all tracings should be coloured on the *back*, as it prevents the possibility of that most unsightly "running" of the lines or figures. Another reason is, because the tints, when looked at from the right side, have a subdued and very pleasing appearance, which they do not possess on the reverse side owing to the nature of the paper or cloth.

On another occasion, I had been engaged on a large

"general arrangement" drawing of engines, boilers and auxiliary machinery, etc., for a twin-screw ironclad. To the uninitiated, this costly and most elaborate plan could only appear as a confused, and, in some places, intensified conglomeration of lines. As all these were in pencil, and additions and alterations had to be made before tracing the drawing, I had to do everything myself. Firstly, because the Admiralty wished the tracing as soon as possible, and, secondly, because I was anxious to get away for my holidays.

It was one of those cases where the engineer in charge of a plan has no time for anything else, and is so carried away by the urgency of the work, as to stand by it almost like a slave by day and by night. So much indeed has this been the case with myself in the years of the past, that I would recommend those who are closely engaged in intellectual work to relax their earnest efforts from time to time, turn their minds into a new channel by way of change, and, fancying themselves young again, avoid the possibility of becoming starched and fossilised members of society, who can neither bow to the right nor bend to the left, lest they should disturb the current of their ever learned thoughts.

Speaking from my own experience, the application of this principle has helped to keep me in continuously splendid health and elastic spirits, for which I am extremely grateful. Celsus advised those who wished to keep in good health to have a *variety* of pursuits, and think of *many* things—this I countersign in full.

After three weeks' close application, the cloth tracing referred to was satisfactorily completed, just in time to enable me to catch the boat for Liverpool, and then the train for the north, glad enough to get off for a little change and relaxation.

These two examples just mentioned will be sufficient to indicate the manner in which, with willing hearts and active hands, we carried through our work when speed combined with excellence were particularly desired, and will fully represent the practice of the present day under similar circumstances, either amongst ambitious staff assistants, or amongst those who have risen to the rank of "Eminent Engineer," with a string of titles attached to their names, or only a simple minded and enthusiastic lover of science, and art, and literature, and music, and all that is beautiful, under the ordinary title of "Consulting Engineer," which I have very happily borne for thirty years.

CHAPTER XVII.

THE NEW WORKS OF SIR W. G. ARMSTRONG, WHITWORTH AND CO., MANCHESTER.

Origin of the Elswick and also the Openshaw Works — Lord Armstrong as an Engineer—Sir Joseph Whitworth's career—Their Wonderful Prosperity—Openshaw Works in detail—*Immense Machine Shops*—Physical and Chemical *Testing Laboratories*—Other Departments—*Show Room* and its Contents—Stupendous Machinery in operation—*Ordnance Department*—Fluid Compressed Steel operations—A 10,000 Ton Hydraulic Press — Its Construction — Heavy Forging Presses — Hollow Forging and its Advantages—Picturesque Shop-floor Scene—*New Gun and Armour Plate Shops*—History of Armour Plates—How Developed—Iron Plates, 22″ thick, shot through—Improved Plates — Their Manufacture — The *Rolling Mill* — A Wonderful Scene—Rolling a Gigantic Plate—Finishing Processes—Story of the Guns and Armour Plates.

HAVING already described locomotive, and railway, and marine works, we shall now make a few remarks concerning the above-named establishment, which is totally different from most others. It is with affectionate regard that I do so, as no other work, outside of those with which I have been professionally associated, has so interested me, for reasons already given, since the day I became an apprentice.

The original establishment was primarily renowned for the manufacture of *Constructive Machinery*, and lat-

terly for guns. Later on—in the New Works—other branches of engineering were introduced, and eventually with large extensions, the manufacture of *Armour Plates* has been carried out in its entirety. And, in addition to these changes, there has been that of partnership with Sir W. G. Armstrong & Co., of Newcastle.

The Elswick Works of this firm are so vast that they employ about 23,000 men upon gunbuilding, hydraulic engineering of all kinds, general engineering, marine engineering and shipbuilding, etc.

The late Lord Armstrong was one of the most remarkable men of his time. As a Newcastle solicitor, in good practice, he one day, while travelling, caught a flash thought from nature which caused him, in 1827, so to enter upon a new career as eventually to perfect a system of hydraulic engineering that has enormously benefited the whole world.

Again, at the time when wrought iron guns were frequently bursting for want of solidity, the construction of an *onion* gave him the idea of building them in *layers* of iron, instead of massive solid blocks which the steam hammer was unable to forge properly. In such prodigious numbers, too, were these made—latterly of steel—as to cause the very rapid extension of his works until they eventually became what they are to-day—one of the engineering wonders of the age.

Sir Joseph Whitworth was, in early days, a working engineer in Maudslay & Field's famous establishment in London, but while he skilfully used the chisel, the

hammer, and the file in the fitting up of engine details, the fire of genius was smouldering, and not long afterwards burst out in the city of Manchester, in a very small way indeed, in the year 1833. Excellence of production brought such a rush of employment that he soon had to open new premises, which were rapidly extended as diversified machines were built, and which swiftly raised the firm to the highest rank.

Mr. Whitworth was a genius of no common order. He was a bold schemer and close thinker, a persistent worker, and one who took the most painstaking care even in the smallest details. Hence his advancement came by leaps and bounds, and his productions gradually became of world-wide celebrity.

His inventions were of a masterly and revolutionary order, since they abolished all previous practice in certain directions, and laid the foundations of the present methods of constructing machinery.

In 1853, Mr. Whitworth was requested by the English Government to undertake the construction of machinery for the improved manufacture of fire arms, and this led him to make a series of exhaustive experiments upon guns themselves, with the object of developing a new system which would give them much greater range and penetrative power than they had hitherto possessed. The great success that attended those investigations opened out quite a new field for the exercise of his inventive faculties, and an enormous increase of business immediately followed, which neces-

sitated the erection of an immense establishment at Openshaw, on the outskirts of Manchester.

In 1857, Mr. Whitworth was elected a Fellow of the Royal Society, and received the degrees of LL.D. Dublin, and D.C.L. Oxford.

In 1868, he received the distinction of the Legion of Honour from Napoleon III, as a token of his appreciation of one of the field guns under trial at that time.

In 1869, he was created a Baronet, and, in addition to these high honours, received others of great importance from a directly professional point of view. By industry and talent he acquired affluence, as well as fame, and generously determined to devote a large portion of the weath thus obtained to the founding of thirty scholarships, each of an annual value of £100, for the continued instruction of youths, selected by open competition for their intelligence and proficiency, in the theory and practice of engineering.

Such then in mere sketchy outline, up to this period, is the history of the man who developed the original premises and built the new ones we are describing.

The Openshaw Works occupy a closely built area of 45 acres in extent, and are filled with the best machinery and appliances for facilitating operations in general work—in the manufacture of great guns, machine tools and tool steel—in the production of extremely diversified castings, and forgings in fluid compressed steel, and in the manufacture of armour plates.

Exteriorly the buildings have a very simple and effective appearance, and are so arranged in plan as to facilitate intercommunication in every way between the various departments. The main portions of the premises consist of a principal *Machine Shop*, 560′ 0″ in length, by 200′ 0″ in breadth, with an extension 700′ 0″ by 100′ 0″. Both of these are divided into bays—as in the other parts of the premises—by rows of iron stanchions that support the roofs and also numerous electric travelling cranes capable of lifting weights up to 125 tons. For extra heavy loads, however, the combined efforts of two cranes are frequently employed.

Close to the former is the *Fluid Steel Compressing and Forging* department, 450′ 0″ by 350′ 0″, containing all the necessary Siemen's furnaces, annealing furnaces, hydraulic presses, engines, pumps, accumulators, etc., employed in the various processes.

Adjacently situated is the *Steel Foundry*, 600′ 0″ by 70′ 0″, where castings combining lightness and strength for engineering work generally are made, and also an *Iron Foundry*, 250′ 0″ by 150′ 0″. This latter supplies the castings for machines, etc., where extra weight is considered an advantage on account of the greater steadiness it produces in their working.

Lofty buildings for the *Oil Hardening* and *Shrinking on* processes, in connection with great gun construction, occupy one corner of the works, while close to these is the *Physical Testing-house*, containing all the machines necessary for conducting the tensile, compressive, bend-

ing, percussive, and other tests, not only in compliance with the most stringent requirements of the firm, but also those of the Admiralty, the British and Foreign Governments, the Board of Trade, and others at home and abroad. So complete is this system in its details, that the above strains, with their various percentages of elongation, contraction of area at point of fracture, and so on, can be read at a glance by means of special instruments of great exactness.

This building additionally contains a *Chemical Testing Laboratory*, which controls in its own way the initial movements connected with the production of the high class steel and iron used throughout the establishment.

As the *Wood-working*, *Smith forging*, and other portions of the premises, are more or less similar to those of the same nature in other establishments of a heavy class, no reference need be made to them.

Then the floors, what a sight! with all sorts of work in progress spread over them in profusion, and amongst which my kind friend, Mr. Barber, the Engineering Manager, acted as pilot.

The *Show Room*, and also the *Offices* for the various members of the firm, the Commercial, and the Scientific staffs, etc., are all arranged upon the most improved lines, and may be considered models of excellence in every respect. The first-named is a valuable adjunct, as it contains numerous examples of finished and tested work, and many kinds of tools, and is also profusely adorned with beautiful photographs of machinery, etc.

The *Drawing Office* is large, handsome, and well lighted, and here it may be stated that tracings from the working drawings are carefully pasted on strong paper, then varnished, and finally secured to boards before being sent into the shops. They are thus protected from dirt, and rendered easy to clean.

Upon entering the great Machine shops I was at once struck with the magnificent proportions of the buildings—their handsome and lofty iron roofs—their wood paved floors—their splendid light, and, above all, the immense quantity of machinery which covered the vast area of the building. There were big lathes to the right engaged on ordinary work; very powerful lathes to the left turning and boring colossal steel ingots for the details of great guns, etc.; gigantic lathes in front, with 30 to 70 ton crank shafts and propeller shafts for naval and mercantile ships, between their centres, one of the latter being in *one* piece 86 feet long, 21″ diameter, and with an 11″ diameter hole bored throughout its entire length. One lathe, which I particularly noted, had a bed 75 feet long, provided with duplex slide rests and eight tools, capable of cutting off about two tons of turnings per hour from a steel forging or casting. It could also be used for turning the very largest crank shafts or guns, for cutting screws of any size out of the solid, and performing all kinds of surfacing work.

Then there were great varieties of slotting, drilling, milling and planing machines of prodigious dimensions, cold sawing machines, and many others as well, in

every direction, fully occupied—a magnificent spectacle for anyone to gaze at. Other admirably designed machines of this class included those for gun wire winding and for gun boring and rifling, one of which is nearly 130 feet in length, and has a cutting tool arrangement that produces an internal finish of the greatest beauty and accuracy.

The planers were very powerfully and numerously represented, and here, too, we found much of a most interesting nature; as we meandered pleasantly along, we came to a dead stop amongst a cluster of these, thirteen of which had the *reversing tool box* in full operation upon steel details.

"Glad to find my old friend of early days doing such excellent work," said I, to my companion, "Look at the amount of time it saves compared with the single cutting tool so much in use. What do *you* think of it?"

Mr. Barber thought as I did, namely, that it was one of the cleverest of Mr. Whitworth's early inventions.

The great disadvantage of slotters and planers alike is the time lost during the backward motion of the cutting tool, or the table, which has variously exercised the minds of many engineers. For almost continuous cutting purposes, however, the aforesaid invention possesses a special value, and is one, too, which has stood the test of about fifty years practice. Forty years ago I saw this tool planing down iron rails into long switches in splendid style, and now I found it in many cases at Openshaw doing the same thing in hard steel engine

details, etc. Hence we may conclude that its continued and economical usefulness to the present day has been abundantly proved.

During our rambles we came upon a newly constructed *Circular Planing Machine*, having a horizontal face plate 28′ 6″ diameter, which could take in work 35′ 0″ diameter between the standards. This colossal engine is used for planing armour-clad turret roller paths, etc., and is fitted with four reversing tool boxes. For machining complete circles the table is revolved continuously in either direction, as may be found most convenient, but if only a segment of a circle is being operated on, both the table and the tools are reversed, so that there is no lost time. Machines of this class are now becoming very popular owing to their varied application, and also to the ease with which the heaviest castings and forgings can be set on their tables, when compared with the old methods of fixing them to a lathe's *vertical* face plate.

A still larger machine, in course of construction, was a *Pit Planer*, of special design, capable of trueing up a surface 60′ 0″ long, by 12′ 0″ wide, the bed of which was 72′ 0″ in length. Here, too, the powers of the reversing tool box were to be utilised in perhaps their most extended form, and with the most advantageous results.

In the *Ordnance Department* there were some curious things, which cannot well be described, as the firm could not permit me to do so. We shall therefore pass on to the *Casting* and *Forging* part of the premises,

where all the colossal machinery for manipulating the heaviest work could be seen.

It may be here stated that the necessity of employing the very strongest metal that could be obtained, caused Sir Joseph Whitworth latterly to direct his attention to the improved manufacture of steel. Crucible steel was tried at first, but as the ingots were too small, and in many cases unsound, they were discarded. He next tried the Bessèmer converter, and finally the Siemens-Martin furnaces, which enabled larger ingots to be made, but here again the attendant imperfections proved a serious drawback, until Sir Joseph overcame them by consolidating the fluid steel under intensely severe hydraulic pressure, which compressed it into a perfectly homogeneous material of great density.

The system of manipulation consists in pouring the melted metal into specially prepared moulds, having a taper sufficient to allow the ingot to be easily withdrawn. These moulds are built with the object of obtaining suitable strength to withstand the action of a 10,000 ton press, which produces about three tons per square inch in the ram cylinder. This pressure is also employed in controlling every movement connected with the transference of the metal from the furnace to the mould—of the mould itself beneath the press—and of the whole of the machinery connected with the operation of fluid steel compression.

The construction and application of this Titan would require elaborate description on account of its unique

arrangement. It may, however, be briefly stated that steel is largely employed in its details—that the hydraulic cylinders are formed of steel hoops and rings of enormous strength, because *solid* metal would be inherently weak, and iron perfectly useless—and that the whole structure is capable of being worked by hand with the greatest ease, precision, and economy.

The steel ingots frequently weigh as much as 70 or 80 tons, and are cast of sufficient length to allow for shrinkage and trimming at the ends, and for turning down to obtain sufficient solidity previous to forging. When, however, they are required for gun-hoops, cylinders, or other hollow work, such as heavy propeller shafts, etc., they are bored out previous to being operated upon in the hydraulic press.

There are various kinds and sizes of *Hydraulic Forging Presses* in the same establishment—this firm being the first to design and develop the above system.

With the introduction of these engines, the important process of hollow forging on a mandrel first became practicable, the advantages of which are obvious; the metal operated on being more thoroughly worked on its interior and exterior surfaces. This is conclusively proved by the convex shape of the ends of all forgings made under the press, while those made under a hammer are concave at the ends, thus showing that the interior has not been properly consolidated. The above presses have now become very popular at

many of the great establishments, where they are most usefully employed in many ways.

Upon entering the department where a variety of small gear is made, such, for example, as taps and dies, and gauges of all descriptions for general use, we found the beautiful little Whitworth *Micrometer Measuring Machines* in full operation. The cylindrical gauges referred to are first turned in the usual way, and then ground with emery wheels to the exact size by means of the extremely delicate touch measurements of these machines.

All the other gauges of length, breadth, and thickness are treated in the same manner, and thus we find that similar details, manufactured by their aid, become interchangeable throughout the world.

The value of the system has already been referred to, so far as bolts and nuts are concerned, but in a much more extended form it permeates the whole domain of Engineering, since spare gear kept in stock, on land and sea, for damaged machinery of every possible description, can be utilised at once without having to wait until new gear is made, thus saving an immense amount of delay and inconvenience.

Amongst the miscellaneous objects of interest we incidentally came across in our rambles were a profusion of great gun barrel and hoop forgings, a cylindrical marine boiler shell segment, 12′ 0″ diameter, forged in one piece from a steel hoop, thus avoiding loss of strength by rivetting, and causing a considerable

saving in weight when compared with a rivetted shell. Steel castings for various purposes, iron castings for others, including machine framings, etc., rifle barrels, bored with mathematical accuracy by special machinery to so many decimals of an inch in diameter, instead of the usual "eighths" and "sixteenths," gun fittings for heavy ordnance, and other gear too numerous to mention, lying about everywhere, sufficient in the aggregate to keep all the machines employed.

The *History of the Armour Plate* invention is peculiarly interesting. During a Continental tour, in 1860, Mr.—afterwards Sir John Brown, of the Atlas Works, Sheffield, happened to be in Toulon just at the time the Imperial ironclad *La Gloire* was lying in the harbour, and attracting much attention owing to the inability of the heaviest naval guns of the period to penetrate her sides. Previous to this she had been a timber three decker, but the French Government had cut her down, and, after covering with armour plates the parts of the hull above water, she was put in commission.

The English Government at once gave orders for the similar conversion of ten large ships of the old wooden type, and this caused Mr. Brown to fancy he saw a field for the exercise of his skill and enterprise. Upon being refused permission to go on board *La Gloire*, he made a minute examination of her exterior, from the nearest point of view, and was thus enabled to ascertain that the armour plates were 5′ 0″ long by

2′ 0″ broad, and $4\frac{3}{4}$″ in thickness, and that they had been made by the hammering process.

"*Forged* plates!" thought the interested visitor, "I think I can do something better than that by *rolling*."

On his return to Sheffield he erected a mill, selected workmen, and personally directed this initial movement to a successful issue, by building up and rolling several small bars of iron into small plates, then similarly, a number of the latter into larger plates, and so on, progressively, until his first five ton armour plates were made. The final process was the most difficult, as the intensity of the white heat thrown off by such a quantity of iron was almost unendurable, and the loss of a few moments whilst conveying the mass from the furnace to the rolls would have been fatal to success.

No sooner had this experiment been satisfactorily accomplished, than formidable competitors arose and keenly contested Mr. Brown's claims to superiority. In 1862, however, this question was finally settled by means of a series of experiments upon plates made in Government establishments, and also in private works, with the result that Sir John Brown obtained gold medals for excellence in armour plating from the French as well as from the English. Thus was commenced a special branch of engineering which very rapidly increased the resources and extent of the above establishment, and gradually revolutionised the construction of naval ships.

When H.M.S. *Inflexible* was commenced in 1874, it

was intended to make her armour of iron 24 inches thick, but before she was ready to receive it, the Armstrong 100 ton gun had completely perforated no less than 22″ solid armour, and also its timber backing.

Sir Joseph Whitworth noted all these movements, and declared at a public banquet that he would make his guns to send shots through every plate that could be manufactured. And so he did, until at last he actually pierced three 5″ armour plates built up together into a solid mass to represent a portion of the side of a vessel. The Atlas Works Company now made a most important movement which neutralised the effects of the improved rifled ordnance, and restored to the ships the supremacy they had lost. Mr. J. D. Ellis, the Managing Director, having discovered that while thick steel plates were cracked and shattered by the heaviest shots, and iron plates were easily perforated by them, conceived the idea of making armour of compound form upon a plan of his own, involving the homogeneous combination of steel and iron, and in this respect he was eminently successful. Then came, in time, wholly steel plates with variously hardened surfaces, and, lastly, those of the present Whitworth manufacture, which is extensively carried on at Openshaw by means of some of the finest and most powerful machinery in existence.

The rolling, especially by night, of a gigantic iron armour plate of say 40 tons, in days gone by, was a sight of profound interest. Let me describe the scene:

At a given signal, a large number of workmen

arrange themselves on each side of the burning fiery furnace, which had heated the plate, and as the doors are opened wide, its interior, containing an immense mass of dazzlingly glistering iron, is fully exposed to view. Some of the men now approach, encased in thin steel armour and wet sacking, as already described, and by means of a gigantic pair of forceps slung from a crane, lay hold of the mass of fizzing, sparkling metal, which is at once drawn by chains to the top of a long iron car. The forceps are removed with great difficulty owing to the intensity of the heat and light, which would be unbearable to any but those inured to them.

When everything is in readiness, the truck is drawn at once to the top of an incline, where the force of gravity alone causes the plate to slide into the jaws of the rolling mill. All hands have now to get under shelter while it passes through the rolls, throwing out jets of liquid metal on all sides, and at the same time making a noise like that of muffled pistol shots. In spite, however, of every precaution that the best workmen can employ, they cannot always escape splashes of melted iron. The revolution of the rollers crushes the plate through to the other side, where it rests for a few moments on an iron truck. The mill is then reversed, after the rolls have been screwed closer to each other. These are again made to bite the plate and drag it back to its former position, thus gradually reducing it to the required thickness.

During every stage of the above process, quantities

of fine sand are spread over the plate, which at once take fire and deposit a coat of silica, or glaze, like that of earthenware. After each discharge of sand, jets of water are played upon the metal, and when this operation is over, men rush forward with wet brooms, having very long handles, and sweep off all the oxidation.

Every time the huge slab passes through the mill, this process is repeated, and its thickness gauged from end to end by the chief roller, who performs the operation under cover of wet cloths, until at last the plate is run on to a table and left to cool. During this period, however, any twist that it may have sustained is levelled off by means of two rollers of about 15 tons each, which are slowly moved backwards and forwards over the surface of the iron while hot, until it becomes perfectly flat. Thus prepared, the plate is ready for the machining and fitting processes, by means of which it is made to take its place accurately on the side of a ship building perhaps hundreds of miles distant.

The story of the guns and armour plates, though very briefly given in this chapter, may still be sufficient to indicate the manner in which eminent practical scientists, in two distinct branches of engineering, may incite each other to attain perfection. It will also form a very good example of individual successes won by the judicious exercise of natural or acquired talents; successes, too, that in the arts of peace, benefit not only whole nations, but the world at large, in endless ways, as we have previously tried to show.

For the information obtained during my visits I have to thank Mr. M. Gledhill, the Managing Director of the Works, who courteously gave me permission to view the premises, and also for so kindly giving me every facility for learning all I wished to know. These favours are more fully appreciable owing to the difficulty of getting into such establishments, as there is so much executed within their borders which it is not considered advisable for the outside world to understand, especially when there are so many professional pirates roaming about, and, therefore, I have confined my remarks entirely to machinery and processes that it would *not* be injudicious to describe.

My first survey of these works kept me very fully occupied throughout. It was indeed a time of sustained "cramming" under the most favourable circumstances, and, although I have similarly inspected many other establishments, the visit described in this chapter is ever to be remembered on account of the valuable experience thus acquired, whilst carefully studying, with Mr. Barber's kind assistance, some of the highest branches of practical science. Further useful notes, only recently obtained, have been embodied in this chapter.

CHAPTER XVIII.

RISE AND PROGRESS OF STEAM NAVIGATION.

First Movements in Water Transport—Romantic Origin of the Sail—Patrick Miller's experimental Steamboat—Beginning of Canal Steam Navigation—Strange Discoveries—First steamer *Comet* on the Clyde—Coasting Steamers—Origin of Peninsular and Oriental Company — *Royal William* of Quebec — First steamer to cross the Atlantic—Her future career—*Sirius* and *Great Western*—How Mr. Cunard originated the Cunard Company—Mr. Charles MacIver—His genius—History of Marine Engineering—Its early Designers — John Penn as an Engineer—Dictator to Admiralties—John Elder and his Compound Engines—Subsequent Improvements—Parsons' Steam Turbine Engines—Their Principle of Action—Early triumphs of Mr. Parsons — Denny's recent Turbine Steamers — Their splendid Success — The new 25 knot Cunard Turbine Steamers — Various Applications of the Turbine Engine — Disasters at Sea—A Flying Inferno.

THE action of a fish while swimming gave the earliest idea of marine propulsion to the ancient people of Assyria, Egypt, Babylonia, and China, who floated on bundles of reeds or inflated skins, propelled by the legs of those who sat upon them; and such methods are still in use on the Nile, the Euphrates, and in the West Indies. The Egyptians, Assyrians, and Babylonians also employed watertight wicker boats, which were propelled by short oars or paddles.

The Chinese used a round boat driven by the palm

of the hand; and Pliny tells us the ancient Britons used a similar boat worked by oars, very much like the coracles which are still employed on some rivers.

The invention of the beautifully simple and effective *sail* is due to a pair of ancient Phœnician lovers who, on one occasion, went out for a row in one of the rudely constructed skiffs of the period. As the gentleman toiled at the oar, a sudden flash of thought caused the lady to fancy that she might be able to help him. In a moment she stood at the bow. In another moment she held up her skirt to catch the breeze, and lo! the skiff moved under the influence of a new power in the history of the world.

The graceful figure of the lady originated the mast, and her arms, yard-arms, whilst her dress gave the idea of the sail, which, in the form fashioned by herself, is still to be found in the Mediterranean, and, in amended form, in the sailing vessels of all nations to the present.

In A.D. 1472, galleys were moved by means of side wheels connected by a shaft having a crank in the middle, which could be worked by manual labour, in a manner similar to that which is sometimes adopted in small yachts, or boats on lakes at the present day, and during succeeding ages various schemes of an extremely primitive character were tried, down to the end of the eighteenth century, but none of them were of any practical value, beyond leading the way to the great future which at that period was just beginning to dawn.

The first experiment which led directly to the intro-

duction of steam navigation was made by Mr. Patrick Miller, of Dalswinton, in Dumfriesshire. This gentleman had made a fortune in Edinburgh as a banker, and having retired from business, devoted the most of his time to useful pursuits. Being also a large shareholder in the Carron Ironworks, he invented the famous "Carronade," a gun at one time most popular in the Navy, but his greatest fame arose out of his efforts to introduce steam power as a means of propelling ships.

The experiment referred to was carried out on the Frith of Forth, June 2nd, 1787, with a little tinned iron plate double-hulled boat, which was laboriously worked by men at a capstan. As, however, a divinity student who was present suggested *steam* as a motive power, William Symington, a young engineer, who was exhibiting a road locomotive in Edinburgh, was asked to make an engine for it.

The next trial took place on Dalswinton Loch, October, 1788, when the highly satisfactory speed of about five miles an hour was obtained. This was the *first steamer* that ever trod the water like a thing of life, and proved the herald of a new and mighty power in river, lake, and ocean navigation.

This experiment forms a landmark in the history of the world, quite as distinct as that of many other important events which have proved new departures in science. The iron boat, the horizontal engine, and the practically useful employment of steam as a motive power, clearly foreshadowed what was to take place in

future years. The Edinburgh banker may therefore be said to have touched the border land of an entirely new system of engineering, which has been developed in the most extended form by many talented inventors down to the present time.

The movement referred to, which had been thus far successfully conducted, was resumed in 1801, when Lord Dundas,—at that period Governor of the Forth and Clyde Canal Company,—employed Symington to construct a small steamboat for towing their barges, and after considerable preparation, a vessel named the *Charlotte Dundas* was completed, and fitted with a horizontal engine having a steam cylinder 22 inches diameter, and a paddle-wheel fixed in the centre of the boat and close to the stern. The performance of this little craft was admirable so far as mere towing was concerned, but the surging motion of the water created by the wheel, and apprehended danger to the banks of the canal, caused the scheme to be abandoned.

Nothing appears to have been done towards the development of steam navigation on canals until the early part of 1830, when a Mr. Houston made an attempt to increase the speed of his boats by experimenting with a light gig on the Ardrossan Canal. To this boat he attached two of the track horses, and, driving them at their utmost speed, found to his surprise that, instead of a heavy rolling surge in front, it actually skimmed smoothly over the surface, and the horses worked with greater ease at the high velocity

than they appeared to do at a lower one. This was so contrary to all the received theories that doubts were entertained concerning the accuracy of the results. Mr. Houston could not investigate the subject for himself; in order, however, to ascertain the true state of affairs, Mr. William Fairbairn, of Manchester, was requested by the Forth and Clyde Canal Company to conduct a series of experiments on a light twin boat, which he had to build for the purpose.

This little boat—the *Lord Dundas*—was 68 ft. long, 11 ft. 6 in. beam, 4 ft. 6 in. deep, and had a 16-inch draught of water, her shell being of iron plates $\frac{1}{16}$th of an inch thick. The engine—which was of about ten horse power—worked a single paddle wheel 9 ft. diameter and 3 ft. 10 inches wide, placed in a trough, extending fore and aft to allow of the flow of water to and from the paddles.

Mr. Fairbairn was at this time a young engineer, full of anxiety by night and by day regarding the success of this scheme. The vessel was at last experimentally tried for a whole day on a long and straight part of the river Irwell, the greatest speed obtained being eight miles an hour, with a heavy surge in front, and a following surge behind, because she carried her propelling power within *herself*, instead of being on the land.

Here Mr. Fairbairn discovered this curious law of nature, which prevented the ship, while in a narrow and shallow waterway, and loaded with her own engines from attaining a higher speed, no matter how much

extra power was applied. When similarly tested on a neighbouring canal the speed went down to six miles, but on the Mersey it rose to *ten* miles an hour. Finally, the Forth and Clyde Canal Company were obliged to run their vessel at what was found to be the most suitable speed of 5 to 5½ miles an hour, and thus abandon all hope of successfully competing with the young locomotives of the period.

The experiments conducted from time to time by Mr. Patrick Miller eventually led to the building of the *Comet*—see page 43—her *side lever* engine being made by Mr. Henry Bell, of Helensburgh. This vessel was so commercially successful that Napier, and also Caird & Co., and Scott & Sinclair, of Greenock, began to build marine engines for the coasting steamers which were rapidly introduced between Glasgow and Belfast, Dublin and Liverpool, and other parts of our Island.

Then began a new era. In 1835, Messrs. Willcox & Anderson, of the Peninsular Company, London, commenced to run steamers to Oporto, Lisbon, Cadiz, and Gibraltar. Subsequent extensions to Mediterranean ports, under the title of—in 1840—the "Peninsular and Oriental Company," and still later extensions to India, China, Japan, and Australia, eventually built up the magnificent fleet of to-day, which, from a passenger point of view, has been rich in romantic stories of the past.

It is believed by most people that the *Sirius* and *Great Western* were, in 1838, the first steamers to successfully cross the Atlantic, this, however, is a

fallacy. In the year 1831, aided by a Government offer of 12,000 dollars, the "Quebec and Halifax Steam Navigation Company" was formed, having amongst its list of shareholders the names of *Samuel*, Henry, and Joseph Cunard. The object of this company was to build a vessel capable of maintaining communication between these cities, encouragement having been given by the success of the numerous steamboats which had been built at Quebec for river and coasting purposes. So much prosperity had attended these vessels that designs had been prepared for the "largest and swiftest vessel afloat," which was at once begun, and eventually launched on 27th April, 1831, under the name of the *Royal William*, her engines of 200 nominal horse power having in the meantime been constructed by Messrs. Bennett & Henderson, of Montreal.

This momentous event—the launch of a steamer 176 feet in length, by 44 feet in breadth, and 17 feet 9 inches in depth—gave the editor of the *Quebec Gazette* quite as large a field for animated and picturesque description as the literary chief of any present-day paper could have in honour of the launch of a 20,000 ton ocean racer. After successfully running locally for some time, it was decided to send the *Royal William* to England, and she accordingly sailed from Quebec on 5th August, 1833, arriving at Pictou, N.S., on the 8th. From this port she sailed on the 18th for London, where she arrived after a passage of nineteen days, including two days detention at sea. Under the name of the *Isabel Segunda*,

she subsequently became the property of the Spanish Government, and was the first steam vessel of war in the history of nations to fire a hostile shot.

When the *Sirius* and *Great Western* had, in 1838, made their famous passages from Cork and Bristol to New York in eighteen and fifteen days respectively, Mr. Samuel Cunard left his Canadian home in 1839 and came to Glasgow, with letters of introduction to numerous influential people. These included Mr. Robert Napier, and Messrs. Burns & MacIver, who at that time owned a very prosperous line of coasting steamers.

This well-timed visit of Mr., afterwards Sir Samuel, Cunard, resulted in the formation, in 1840, of the "British and North American Royal Mail Steam Packet Company." This, however, was afterwards changed into the "*Cunard* Line," in honour of the Quebec citizen who had given it the start in life, and thus set a-rolling the ball of prosperity for ocean steam navigation all over the world, for all time.

Now that so many years have rolled away, it may only be added that the enterprising partners of Sir Samuel Cunard—the MacIvers and the Burns—proved themselves to be amply capable of sustaining the grave responsibility they then assumed. So capable, indeed, that although they had to learn for themselves the very rudiments of steam navigation, they, nevertheless, ran their ships for sixty years across the stormy Atlantic without losing a life, a letter, or a

ship, a splendid record, which has since been as splendidly maintained.

Mr. Charles MacIver was so essentially a genius that he was able to monarchise his whole Company. He knew *everything* of an inside or an outside nature connected with his ships, and his captains, officers, and engineers specially made themselves masters of their respective sciences, hence, to a very large extent, indeed, their unique success for so long a period. Mr. MacIver was kind and good to all. He acted as a father to those he employed, although a very strict disciplinarian. He prospered greatly in everything he undertook, until, in later years, the unavoidable vicissitudes of commerce induced changes which are of such modern date as not to require description.

The *Marine Engine* has a history of its own, as well as the ships which it propels. From the time of the *Comet* onwards to the "forties," ten, fifteen, and twenty pound steam prevailed, and the side-lever engines of the period had their framings designed more in accordance with the *massive* architecture of Greece and Rome than with the elegance of proportion, accessibility of working parts, and great saving of weight which were fully developed in later years.

During the "fifties," the steam pressure went up to twenty-five pounds per square inch, and the afterwards very famous firms which, even then, were well to the fore, had each their own special type of engines, and

also of details, to apparently avoid the suspicion of copying from each other. In Scotland, the firm of Robert Napier & Sons took the lead, as previously described, and in England, that of John Penn, of Greenwich.

Mr. Penn was the living embodiment of everything that could make a successful engineer. When, therefore, the Admiralty invited him to re-model the machinery of H.M.S. *Black Eagle* he took out her massive old-fashioned engines, and put in his own exquisitely beautiful "oscillators," and thus not only reduced the weight by about one half, but decreased the coal consumption, and accelerated the speed of the ship, the result being an immense increase of business. Then, again, in the early "fifties," when the old sailing ships of the navy were being fitted with auxiliary machinery to help them against adverse winds and calms, Mr. Penn's horizontal double-trunk engines became so popular that British and Foreign Governments overwhelmed him with orders, and practically made him their engineering dictator.

To myself, all Mr. Penn's work was a source of great admiration. The general design of his machinery was not only most admirable, but its details were remarkable for beauty of form and exquisite finish, and for great lightness combined with strength. Sometimes, ... lieve, they broke down, well—"make 'em stronger ... me," was the order of the day. Mr. Penn had ... derful career. His machinery commanded the

highest price at all times, and when he died he left a fortune of £2,000,000.

Mr. David Elder was another of those who made master-strokes in marine engine designing, and amongst the ever memorable "fifties" Mr. John Elder introduced his splendid *Compound Engines*, with high pressure *cylindrical* boilers, both of which saved much coal, and in course of time became universal.

In 1861, Messrs. Tod & Macgregor were requested by the Inman Company to build for them the S.S. *City of New York*, of 2,500 tons, with *thirty pound* steam horizontal engines of the ordinary type. Then came a Mr. Davidson buzzing around the engineers of Glasgow with a patent *surface condenser* arrangement which, he said, "would abolish for ever the wasteful jet condenser of the past." Some favoured Mr. Davidson, but others did not. T. & M., however, put them into the above vessel, and soon afterwards the system became general.

Amongst the "seventies" and "eighties," came the *triple expansion* engines with 150, and also the *quadruple expansion* engines with 180 pound steam. Next followed the *five-crank quadruples*, with steam going up—up—up, until it stands to-day at nearly 300 pounds per square inch; and now we are entering, with the *steam turbine machinery*, upon the greatest revolution yet known in marine engineering.

The Steam Turbine Engine.

The principle of action of the *Water Turbine*, inside

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of the casing which contains it, may be compared to that of the curved vane ventilators, which, rapidly revolved by the wind, are frequently to be seen on housetop chimneys. The *Steam Turbine*, on the other hand, is closely assimilated with the well-known wind wheel, whose continuously radial vanes are placed square against the wind to obtain their greatest amount of motive power. The main difference, however, between the two turbines is, that the *steam* mechanism consists of a number of rings of small and specially curved vanes or blades, half of which are annularly attached to a shaft of large diameter which revolves inside a cylinder, and allows its blades almost to touch it, the other half being fixed to the cylinder itself, between the former, and nearly touching the shaft, as shown in the Plate opposite page 286, thus constituting a series of what are termed "fixed and moving blades," through which the steam passes in its course from one end of the cylinder to the other, giving out its power to the moving blades and shaft, as, guided by the fixed ones, it passes from ring to ring, undergoing considerable expansion as it does so. For land purposes the whole expansion takes place in one long cylinder, but for marine work two or three cylinders, with separate shafts, are used in succession.

It will thus be seen that, instead of having an unscientific application of power, as in the reciprocating engine, we have here—what inventors have been striving to obtain for 100 years—an ideal *rotary* engine, as

proved by its numerous highly successful performances on land and sea.

The efficiency of the machinery is further increased by the manner in which its power is transmitted through three or four shafts, with one small propeller on each, thus ensuring greater steadiness in running, as well as higher speed, than in ships having the ordinary type of engines and screws.

The Hon. Charles A. Parsons—the inventor of the Steam Turbine Engine—is the son of the Earl of Rosse, of great telescope fame, and constructed his first steam turbine dynamo in 1884, various similar installations following. In 1893–4, the "Marine Steam Turbine Company" was formed, with Mr. Parsons as its Managing Director, which resulted in the building of the experimental torpedo boat *Turbinia*, the unexampled speed of which was 34½ knots or 39½ miles per hour, the revolutions of the screws being 2,000 per minute, with a steam pressure of 210 pounds per square inch.

As the steam turbine advanced in popularity, it became necessary for the Company to build new works in Newcastle and at Wallsend-on-Tyne for its manufacture for land and marine purposes. Since then, the application of this machinery to naval vessels, and to river and ocean steamers, has increased so rapidly that many firms have obtained licenses for its construction for land and marine purposes from Messrs. Parsons & Co. and the Parsons' Marine Steam Turbine Company Limited to enable them to construct it for themselves.

Passing over H.M.S. *Cobra* and *Viper* of 42 miles per hour, and numerous other vessels which have thus been engined with great advantage, we come to the more recent Clyde river steamers, *King Edward* and *Queen Alexandra*, built by Messrs. Denny Brothers, the former being the first passenger vessel propelled by turbine engines supplied by the Parsons' Company; the latter being a larger and more recent ship.

The dimensions of the *Queen Alexandra*—shown in the frontispiece—are:—Length 270 feet, breadth 32 feet, and draught of water 6′ 6″, the engines being 4,400 indicated horse power. The speed on trial trip was 21·63 knots, or $24\frac{3}{4}$ miles per hour, the revolutions of the central screw shaft being 750, and those of the side shafts 1,090 per minute. Since then, many other very successful turbine passenger, etc., steamers, of much larger size and higher speed have been built and engined by the same firms.

The advantages chiefly claimed by the constructors of these engines are:—Saving of coal, less weight and space in ship, higher speed with extreme steadiness in running, less first cost, and less expense in working and maintenance, etc., all of which in combination have already produced results which will become more apparent as the days go by, the grandest recent movement of all in this direction being that of the Cunard Company, whose new ocean racers, 760 feet long by 88 feet beam, are to have fully 70,000 horse power turbine machinery, capable not only of driving each ship at a

speed of 25 knots an hour, but, aided by numerous minor auxiliary engines, of performing all the interior daily work, and especially in time of fire or flood.

As the principle of action of the steam turbine engine has already been described, its interior details may, to some extent, be understood from the adjacent sectional view of a *Turbo Blowing Engine*, by Messrs. Parsons & Co. The alternate annular rings of fixed and moving blades are clearly shown in a small portion of the steam-driving cylinder on the left, and in the air blowing cylinder on the right.

With various modifications suited to the driving of dynamos, ships, etc., to which these engines are now extensively applied, the same view will also explain the principle of action, although it does not illustrate the outside accessories of condenser, circulating and feed and bilge, etc., pumps, and general fittings and mountings suited to the work they have to perform.

It may be added that, in a ship, these engines lie very low, and although they have none of the beautiful array of polished piston rods, connecting rods, crank shafts, valve gear, levers, etc., which adorn reciprocating machinery, they, nevertheless, show very clearly how much admirable work can be done without them.

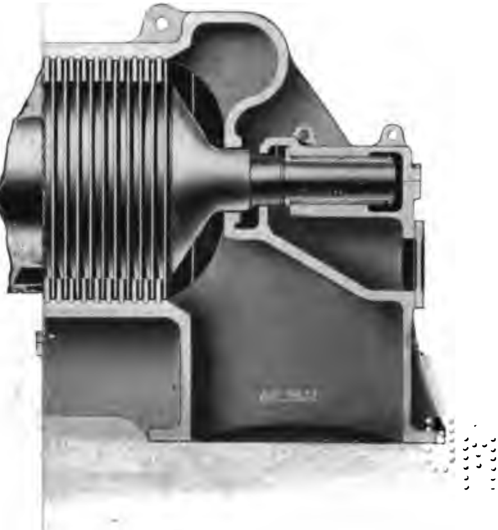
Just a few words about those *Disasters at Sea* which have painfully diversified the history of steam navigation, and which have been caused by rock, sandbank, collision, storm, fire, etc. Not one of these, however, even where the loss of life has been greatest, can equal,

for accumulated horrors, the burning of the R.M.S. *Amazon*, about which a book was written at the time.

This new and magnificent timber-built ship—shown on page 289—left Southampton on January 2, 1852, for the West Indies, with a crew of 113 and 50 passengers, the vessel and cargo costing £100,000. On the third night at sea, when in the midst of a strong adverse gale, fire broke out at the forward funnel, which swept aft with such rapidity that the engines could not be stopped. Nearly all the boats were destroyed, and in a few moments the fire crashed into the saloon amongst the bewildered passengers, thus producing a hideous transformation scene which has never been exceeded in imagination by the wildest writer of fiction.

Through the deck of this Flying Inferno, with engines working red hot, and boilers at the bursting point, people of both sexes, just roused from bed, fell into the raging furnace below, others being enveloped by flames as they stood huddled together. Soon afterwards the ship blew up and sank, only 59 being saved—Lieutenant Grylls, R.N., a passenger, taking charge of one boat, and Midshipman Vincent another, the ship's officers being all lost.

This and subsequent disasters on land and sea so attracted the attention of the engineering world as to have produced results which have given to travelling the unique safety it possesses to-day.



AIR TURBINES.

CHAPTER XIX.

ELECTRICAL AND OTHER MOTIVE POWER ENGINEERING.

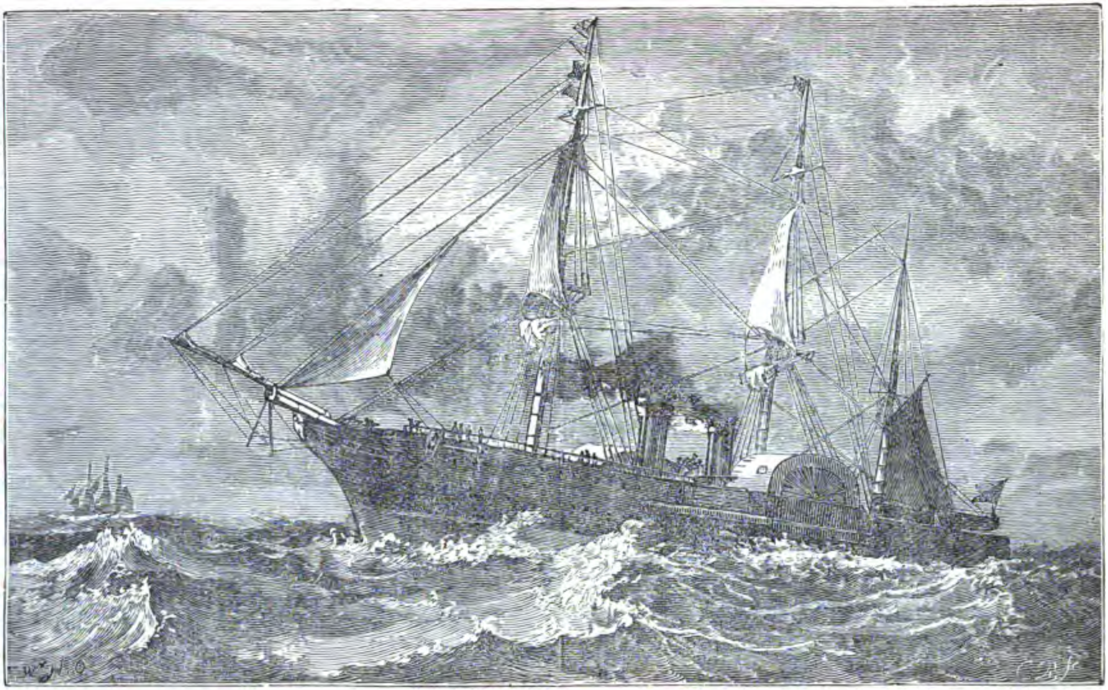
History of the Steam Boiler—Its Development to the Present—Chemistry of Water—Curious Practical Facts—The *Water Tube Boiler*—Its Special Advantages—Great Economy of Fuel—*Gas and Oil Engines*—Their extreme usefulness—Cheap Gas Producing Plant—*Electrical Engineering*—Its wonderful development—Paradoxes of Electricity—Long Distance Power Transmission—Electrical Terms Described—How a Dynamo becomes a Motor—Its Main Details—Various Applications of Electricity—Immense Hydraulic Electric Power Stations—Wonderful Success of the Electric Tramway System—Great Electrical Engineering Works—Notes upon Special Visits to Them—Electrical Engineering as a Profession—Colossal Constructive Machines in the Works.

As the Marine Engine has a history of its own, so also have the *Boilers* from which it receives life. Originally very crude steam producers, they were—during the "twenties" and "thirties" of last century—developed into the thin shell, stayed in every direction, ten to fifteen pound steam, *square box* formation, which was continued throughout the following decades up to the "sixties," the pressure having risen by stages to 25 and 30 pounds. Owing to the advance in the pressure to about 200 pounds, due to the introduction of the compound, triple and quadruple expansion engines during

the "sixties," "seventies," and "eighties," the specially designed *cylindrical* boiler was the only safe one, since, with very strongly stayed flat ends, the barrel portion had strength enough in itself to withstand any strain to which it could be exposed.

During the era of the jet condenser, much of the sea water that condensed the steam from the cylinders by sprayed contact with it, was pumped into the boilers as compensation for the fluid evaporated. This caused the formation of a destructive scale in their insides, which not only prevented the heat from the furnaces from acting efficiently upon the water around them, and thus wasted much coal, but seriously endangered the safety of a ship by threatened and even *actual* explosions, which various internally applied "anti-corrosives" or "scale preventers" were intended to avert.

When the surface condenser came into use, the sea water, instead of mixing with the steam, as formerly, passed through miles of small brass tubes, the *cold* surfaces of which changed the steam into practically *fresh* water, which, pumped as usual into the boilers, was expected to abolish all the above patent medicines. Here, however, was a disappointment. It was found that the lubricants used in the steam cylinders, etc., so chemically acted upon the vapour as to cause it to corrode, pit, and destroy the condenser tubes, and then so vitiate the water due to condensation as to similarly damage the insides of the boilers. Eventually, Mr. Edmiston, C.E., of Liverpool, and others, invented methods of



R.M.S. "AMAZON" SIGNALLING.

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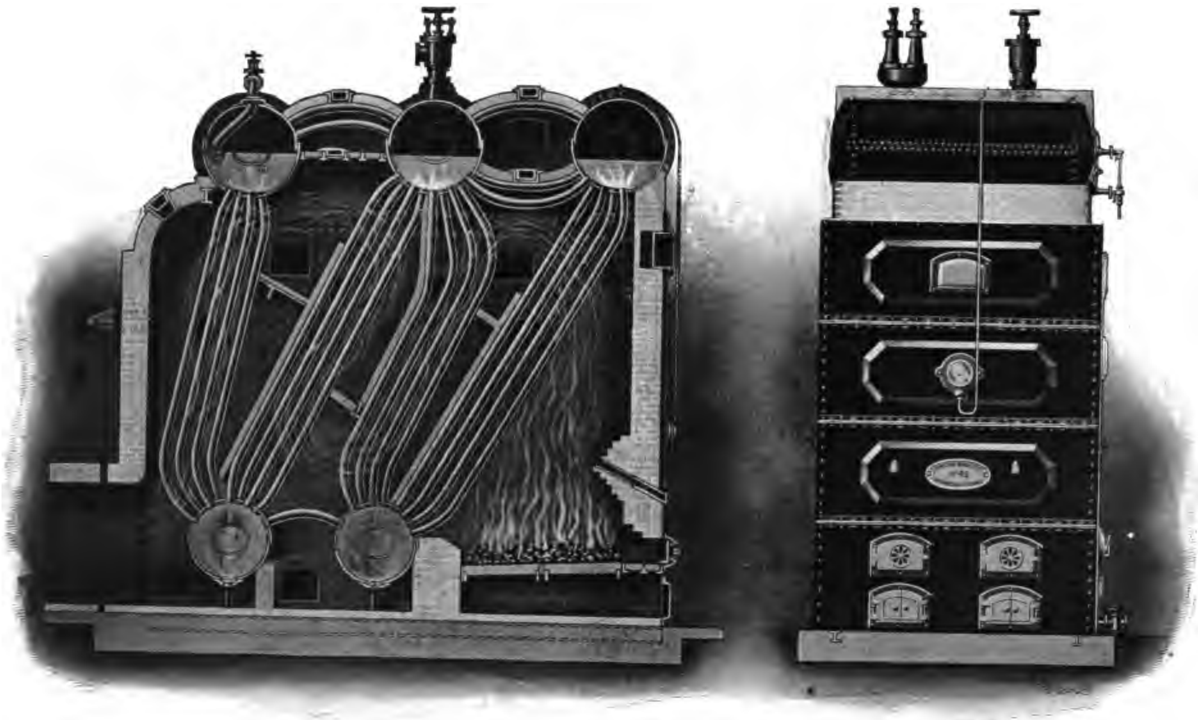
purifying the feed water *before* it entered the boilers, which, indeed, was the true solution of the difficulty. A solution, too, quite as rational and logical as that of purifying the water we drink, previous to entering our systems, instead of first swallowing foul water, and then taking medicines to cure the diseases thus engendered.

Pure, though very hard water, too, has its serious evils. It causes extravagant expenditure of soap and soda, and tea, etc.; it is very bad for laundry work; it forms hard scale in steam and other boilers; it is objectionable for manufacturing purposes generally; and, in short, from various points of view, it causes a financial loss in great cities almost beyond belief.

On the other hand, pure water without a little *lime* hardness, is bad for bone making. Hence, for some time after the Loch Katrine water was led into Glasgow, it created extraordinarily frequent limb deformities amongst the children of the working classes, as I myself noted. In the main, therefore, the chemistry of water is a most important study.

The greatest improvement of recent times, in connection with steam producers, has been the invention of the *Water Tube Boiler*, of which there are now various kinds, whose details of construction, as well as individual value, have caused much discussion amongst some of the ablest engineers. The features which essentially distinguish these boilers from others have already been referred to on page 100, with an accompanying illustration, showing the simplicity of the *naked* structure.



WATER TUBE BOILER—LONGITUDINAL SECTION AND END ELEVATION.

The adjacent views, however, of one of the productions of the Stirling Boiler Company, of Edinburgh, not only show another system of construction, but the brickwork, general fittings, and also the manner in which the heated gases circulate amongst the tubes on their way to the outlet to the chimney. Briefly summarised, the numerous advantages of these boilers include the following :—

Smokelessness — simplicity of construction, and avoidance of all stays—cleanliness—full utilisation of heat—practically perfect circulation—freedom of expansion and contraction in every direction—accessibility of parts—speed in raising steam, and very high safe pressure of same—great facility of transportation and erection, and easy adaptation to the requirements of steam navigation. As evidence of the popularity of these boilers, it may be mentioned that they have been extensively used in Electricity Generating Stations, Iron, Steel, and Engineering Works, Mills, etc., and also abroad, especially where they can be adapted for the burning of megass, or other inferior fuel.

The history of water tube boilers, for employment on land or sea, contains much that is romantic and disappointing, but of these, as of most other famous inventions—including the Sewing machine, which took one hundred years to perfect—it may be said that, as plan after plan was approved of, temporarily discarded, and finally matured, their future success lay entirely in the hands of the mechanical engineer, who could design

and arrange their *details* to the best advantage. An advantage, too, which resulted in reducing the coal consumption to one-eighth of what it was sixty years ago. Thus enabling steam vessels to carry correspondingly more cargo, and to traverse very long distances without requiring to call at any coaling port. This, however, has been partly due to the sweeping improvements in marine engineering previously described.

Gas and Oil Engines.

Two of the most valuable motors of to-day are the above named engines, but as they are very similar to each other, the following remarks will chiefly apply to the former.

The *Gas Engine* utilises heat force in a manner quite different from that of the steam engine—combustion, explosion, and expansion being combined in a peculiar way. With the latter, there is an unavoidable waste of fuel in raising steam, and also during intervals when the engine is idle, or when intermittently employed. With the former, however, nothing of this kind exists, as the engine begins to work at once when the gas is lit, and stops when it is extinguished. The motion of the present machinery is now practically perfect, owing to the admirable design of its details, and the application of either one or two heavy fly wheels that store up the intermittent energy, and thus produce very smooth and steady working.

Gas engines do not require such careful attention as

those having steam boilers, as there is neither fire to feed nor water level to maintain, nor, indeed, any of the critical supervision so constantly needed by the latter. Hence, the former have been found very useful in private houses, printing establishments, warehouses, workshops, and for a variety of other purposes, including dynamo driving, etc. In city workshops, or in crowded buildings generally, a gas engine has the special advantage of freedom from the risk of fire, consequently, the cost of insurance is not so great as in other cases.

Besides these qualifications, its cleanliness, simplicity, ease in manipulation, and great compactness of arrangement are strong recomendations, not to mention the facility with which it can be used as an auxiliary to large steam engines for performing useful work when only a small amount of power is required, or where the service is too small, or too intermittent for the economical employment of a steam engine. A good example of this, at the Crewe Works, has already been given.

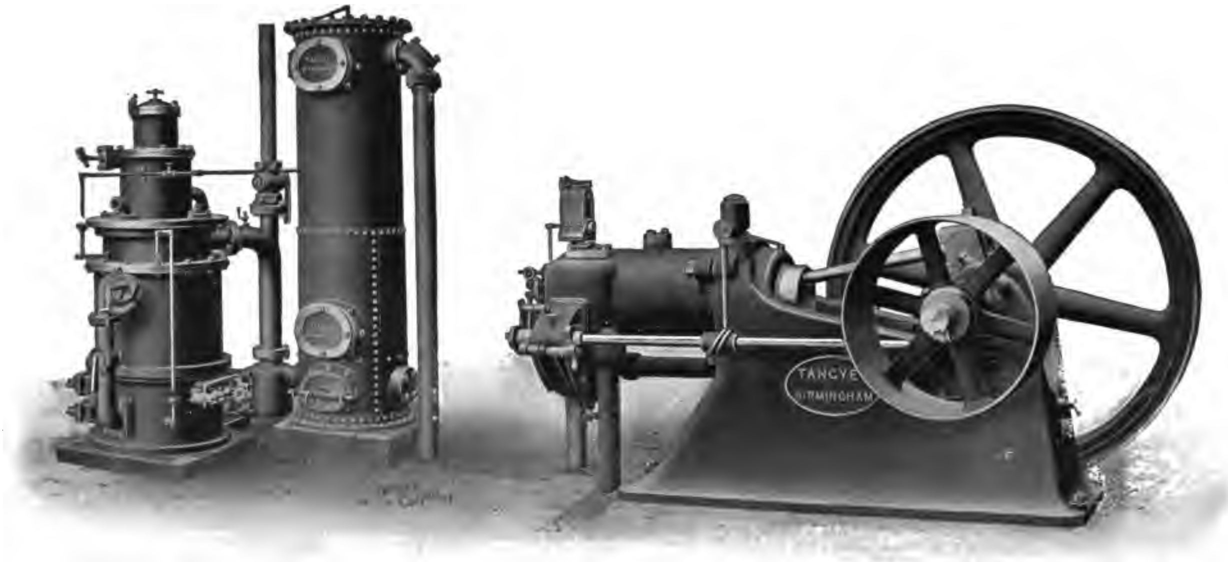
If these engines could only be used where a town's supply was available, their employment would be much restricted, especially if the gas is costly. To get over this difficulty, an improved *Gas-producing Plant*, of the "*Suction*" order, as shown on the next illustration, has been designed by Messrs. Tangye, in view of the increasing demand for engines of large power which, though they cannot be worked economically from the

town supply, can, with a suitable gas-producer, be worked more cheaply than the best steam engine. The plant possesses many special features and advantages which render it valuable in places where town's gas is not available, and where economy in fuel is of the first importance. Where, also, simplicity of construction, and arrangement and maintenance should be supreme.

A more extensive plant of the *pressure* type—designed by the same firm—is employed where gas suitable for heating and motive power purposes can be manufactured. The advantages of both systems are numerous and important, but need not here be referred to, as ordinary readers would not care for such a technical description, and professionals can otherwise, in lengthy and *learned* form, obtain all the information they wish.

The views, however, on the adjacent plate clearly illustrate the *Gas Producer* and *Gas Engine*, of 35 indicated horse power combined, ready for use. In the former, by the aid of an ordinary labourer, the fuel is burnt in the left hand vertical cylinder, the gas from which passes through pipes to the large vertical cylinder, where it is purified and prepared for suction by the gas engine for motive power purposes. By this means, ten horse power may be developed for less than one penny per horse power per hour.

The *Petroleum Engine*, which is very similar to the gas engine in appearance, is entirely independent of all these accessories, its only requirement being an adjacent oil cistern from which it draws its motive power. So



"SUCTION" GAS PRODUCER AND GAS ENGINE COMBINED.

completely is this accomplished that it has rapidly become a very popular engine, especially in out-of-the-way places, for a great variety of purposes, and for giving motion to yachts, launches, traction engines, &c., the cost of working being very small.

It may be added, by way of contrast in application, that petroleum and other hydro-carbons have been very successfully and extensively applied to locomotives, for steam-raising purposes alone, upon the system invented by Mr. James Holden, Locomotive Superintendent of the Great Eastern Railway, and that, as one example out of many of its value, when the Arlberg Tunnel became very unhealthy, owing to the foul air created by the coal-burning engines, the application of his system to them entirely remedied the evil. On the Great Eastern Railway all the more important trains, including numerous special trains conveying Royal Personages, are drawn by engines fitted with Mr. Holden's apparatus for burning liquid fuel.

Electrical Engineering.

Here we now touch the borders of a Science which has lain dead since the world began. The mighty Powers of Nature—especially steam, water and electricity—were within easy reach of mankind, ready for use in multitudinous ways, and yet none of the Ancients, and hardly any of the Moderns could appreciate their value and appropriate their energy until within the last hundred years—*very* strange to say.

The wonderful practical development of *Electrical Engineering*, as we now have it, has been due to the sustained efforts of many minds during the nineteenth century, the talented philosophers and engineers of which paved the way for its useful application during recent years. The electrical engineer of to-day, although supposed to belong to a new race of professionals, is neither more nor less than the mechanical practitioner promoted a step higher, and while still utilising in the fullest degree his former experience, is adapting it to a previously neglected force of nature.

The power referred to has been described by Sir William H. Preece—late Engineer-in-Chief for many years to the General Post Office, London—as a "subtle and invisible force that pervades the earth and permeates the heavens, whose energy can be utilised when desired, but which disappears when done with—like the snowfall on the river, a moment white then gone for ever.

"The *paradoxes* of electricity are more numerous than some would imagine. For instance, though invisible it can be made to produce the most powerful light known, and although noiseless it can create deafening peals of thunder, or operate the most delicate of all acoustic instruments—the telephone. Although existing in unlimited quantities of powerless form in and around the earth, it can be used to drive motors as powerful as a great steam engine, or as minute as a watch. Although we cannot touch it or handle it, yet we can measure it

with the greatest accuracy, and although it has apparently no velocity, its speed is almost infinite. Although not a chemical, its produces very powerful chemical action; and although it cannot be burnt, it nevertheless produces the greatest known heat. Amongst other paradoxes, perhaps the greatest is that, although the laws of electricity are more definitely determined than those in many other branches of science, we cannot say what this wonderful agent really is, and so, for want of a better term, we call it a fluid."

Like water-power, it can be stored up or accumulated for future use, and it possesses the great advantage of being extremely portable, and capable of having its direction and intensity easily changed. It can be taken round corners into all sorts of nooks, crannies, and crevices, and up-hill or down-hill, much more easily than gas or water, and from one central station it can be made to sweep very many miles around. Another of its peculiarities is the ease with which the waste power of rivers can be variously utilised for electric storage purposes, so that energy may be distributed even on the most colossal scale, as some recent works on the Continent, and in Canada and America, abundantly testify.

The ordinary terms used by electricians may be explained in the simplest manner as follows:—

Electro-Motive Force, Potential, or Volts, are one and the same thing, the last named being derived from Volta, who was a noted Italian experimentalist. These

terms apply to the pressure of the current in the same manner that pounds per square inch is used by engineers. per unit

Ampères, or *Current*—the former title being derived from Dr. Ampère, a French philosopher—is the quantity of electricity given by a dynamo or passing along a wire, and may be compared with the quantity of water or steam passing through a pipe. per unit.

Ohm, or *Resistance*—derived from Dr. G. S. Ohm, a famous author—is the term applied to the unit of resistance, and may be compared to the friction opposed to water or steam whilst passing through a pipe.

A *Dynamo* is a machine so actuated by a steam or other engine as to *generate* electricity by the operation of rotating conductors—usually in the form of coils of copper wire—in a magnetic field, upon the principle discovered by Dr. Faraday, in 1831. If, however, the the same dynamo received a supply of electricity through a cable or wire, from a more or less distant source, for driving purposes—as in some of the machines illustrated in this volume—it then becomes a *Motor*, but is worked under different conditions.

Although possessing an enormous range of power—some of the heaviest constructive machines being employed in its manufacture—the Dynamo is, nevertheless extremely simple, as may be gathered from the view of a "50 C." example shown opposite page 300. This represents one of a series of five standard types designed by Messrs. Tangye, some of which, of

an open type, are well adapted for clean and dry situations, whilst those of the completely *closed* kind, as shown in plate opposite p. 154, are best suited for working in dusty or damp places, all the parts, however, being easily accessible for examination. The machine illustrated consists of the following leading parts:—

The *Field Magnets*, within which the armature revolves at high speed, one of which is visible inside the gridiron part of the outer casing.

The *Armature*, the core of which is keyed to the shaft, its outer portion consisting of windings of the high conductivity copper wire generally used, suitably prepared and held in proper position for the work it has to perform. One end of this armature is visible just inside the casing. Between this and the wheel on the right is shown a small portion of the *Commutator*, which is made of a large number of horizontal insulated segments of copper hydraulically pressed on a metal centre fixed on the shaft.

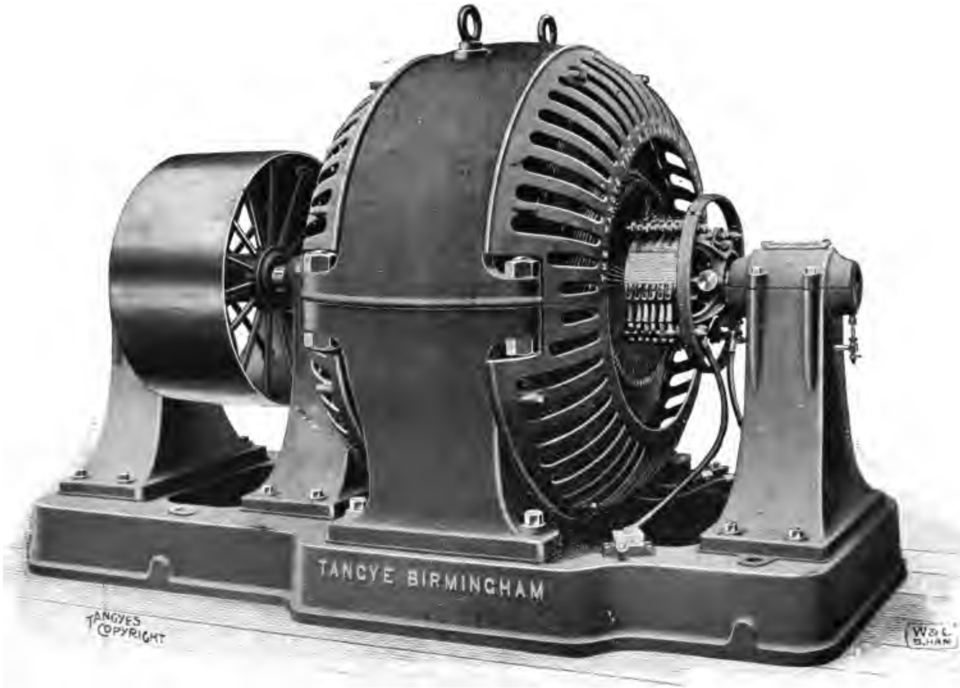
The little *Brush Holders* shown above and below the commutator, are each fitted with a solid truncated wedge-shaped *Brush* of high conductivity carbon, each of which bears against the commutator with a soft elastic pressure, and is capable of being easily adjusted or replaced. Upon setting the machine in motion, the electric current, which immediately passes from the region of the armature and magnets into the commutator, is collected (or absorbed) by these brushes, much in the same way as a sponge absorbs water, and then

transmitted through insulated cables or wires to any desired point for practical use.

The *Steel Shaft*, to which the armature and commutator are keyed, has a long bearing at each end well lubricated, driving power being transmitted to the shaft by means of the *Belt Pulley* shewn in the view, or otherwise, by a steam or gas, etc., engine directly attached.

These extremely brief remarks concerning the main details of the dynamo are chiefly given for the benefit of general readers, who, I hope, may find them useful, especially whilst watching the swift, and beautiful motion of one of these machines.

The *Applications of Electricity* are countless, and may be said to range from the operation of a dentist's drill to the direct driving of the heaviest classes of machinery to be found in engineering or any other works. For power supply purposes at central stations; for the electric lighting of towns, and the working of tramways and railways, or for all combined, its generation may amount, as with the St. Lawrence River Power Company—by means of turbines—to 75,000 horse power at one station. Similarly, to 100,000 horse power for the Third Avenue Railway, New York, and to as much as 200,000 horse power for the Manhattan Elevated Railway of the same city. Still more powerful stations, in the aggregate, have been built on both the American and Canadian sides of the Niagara River, at the Falls. So much, indeed, has this been the case, that if this process is continued long enough, that great Cataract will event-



"C" TYPE DYNAMO.

ually exist only in history, but, never mind, it will last *our* time.

During the year 1903, the Liverpool Corporation Electric Tramways carried about 113,057,234 passengers, the money earned being £524,468, an increase over the previous year of £17,740. Personally speaking, as one who travelled every day for a long time by these lines, I have much pleasure in stating that the handsome, spacious, well-lighted, and very comfortable carriages provided by the Corporation, combined with rapid transit and low fares, under the talented superintendence of Mr. C. R. Bellamy—the General Manager—has greatly conduced to place these tramways among the most prosperous in the kingdom.

The enormous expansion of the tramway system throughout the land; the initiation of numerous electric railways, and the rapid extension of electrically-driven machinery, foreshadow a time in the not distant future, when this Force of Nature will perhaps be the best used of them all, especially in regions where the cheap power of rivers is abundantly to be had for turbine-driven purposes. Turbines, too, of extraordinarily small size and extremely simple construction, and of wonderful efficiency when they can be conveniently located where high heads of water are available.

Owing to the great advances made during recent years in the application of electricity for endless purposes, we have now some of the largest establishments in the country engaged in the manufacture of dynamos,

motors, and other machinery, the works of the British Westinghouse Company, in Manchester, being the most extensive, and one of the best equipped.

Amongst those, however, best known to myself, is the establishment termed the "English Electric Works" at Preston, owned by Messrs. Dick, Kerr & Co., which, only recently, I had the pleasure of carefully surveying. These electrically driven works form a very extensive addition to what was formerly a series of electric railway and car building shops, but, so rapidly has the tramway system been developed of late, that this splendid new establishment had to be built on the most improved principles, and supplied with the latest and best labour-saving machinery in existence, with a view to thorough organisation and standardisation all over the premises.

Under the guidance of Mr. Connor—the manager—I was charmingly shewn around the premises, and was thus enabled to have a very clear idea of what his firm had done to render dynamo and motor, &c., building, not only a high science, but one which would prove of great advantage to multitudes, the Company's Works in Kilmarnock having been long well known for the manufacture of light locomotives, portable railways, and all their accessories. So far as orders in hand which filled the shops, and those in prospect were concerned, this firm—at the time of my visit—seemed to be in touch with the world at large, and, as all the other works of this nature I had previously visited, including those

named in early chapters, were fully occupied, it seemed that *Electrical Engineering* now overshadowed all the other mechanical branches in importance.

I could not but admire the skill with which such large buildings were designed so as to have the greatest constructional strength with the least expenditure of material; the greatest amount of *natural* light, and the systematic arrangement of machines and processes to enable the work to be executed with as much rapidity and excellence as possible. Amongst the machines which profusely covered the floors of a shop 900 feet in length by 120 feet in breadth, were many of special and somewhat unusual designs, and a few of enormous size, one being a huge planing machine having a bed 24 feet in length, and a total weight of 75 tons.

Another was a boring mill capable of boring up to 24 feet diameter, and having a weight of fully 100 tons. Still another was a universal boring and milling machine, which occupied even more space, and could with ease bore and mill, and otherwise operate to the finish, the largest generator frame castings which could be fixed upon its table, without moving the castings. Facts like these will illustrate the sometimes cyclopean nature of the electrical engineering of to-day, taken in connection with the colossal power-houses that are now being built, and the extremely powerful hydraulic and steam-installations which they now require for driving purposes.

CHAPTER XX.

VARIED SKETCHES OF ENGINEERING LIFE.

Snapshot Glances at the Early Engineers—Gigantic reclamation of Land in England—How London and the Thames were Engineered — Internal Communications — *Metcalf*, the Blind Roadmaker—*John Rennie*, and his Works—Docks, Harbours, Canals, and Railways—The Mechanical Engineers and their Masterstrokes—How they all built up the Science of Civil Engineering—Marvels of the Future—*Marine Engineering at Sea*—Sea-going Engineers and their Duties—The Machinery for all purposes in a great Ocean Liner—Characteristics of the Engine-room Staff—How a Mail Steamer is kept in perfect order—A "Dog Watch" Story—Life as a *Railway Surveyor*—The Surveyors' Institution of London—Varied Courses of Study—Enormous difficulties of Transatlantic Surveys—A curious Rocky Mountain Incident.

In this chapter I may appropriately refer to the efforts of some of the early engineers who helped to make our island a suitable home for the coming millions. All the more so as those Pioneers of Science had so much to contend against, and so many difficulties to overcome which required all the energy, and perseverance, and native skill, and patience they could bring to bear upon their work, as the admirable books of the late Mr. Samuel Smiles so fully describe.

Not to go further back than 300 years ago, a large portion of England had to be drained, and the Thames

regulated; London had to be developed; roads all over the country had to be made, and the rivers bridged; canals had to be excavated, and railways constructed; steam navigation introduced, and manufactures of all kinds greatly improved and extended. In short, the primitive machinery of our island had to be set in motion at all points before commercial success could be obtained.

In the sixteenth century, large portions of four counties, occupying what was known as the "Great Fen Level," was a very shallow inland sea, dotted here and there with islets, and there and here with villages which formed the nucleus of some of the present towns. It was in many places an unhealthy swamp in dry weather, and an overwhelming flood in the rainy season. For 200 years bishops, barons, abbots, engineers and others, had tried to remedy the evil, but all of them failed, as the whole territory was so flat, and so near the level of the sea, that the rivers had hardly any outfall. At last, *Cornelius Vermuyden* was brought from Holland, and *he* did the deed. Thus, in time, 680,000 acres of rich farming land was reclaimed from the flood, the history of which is as good as a romance.

Another of the most important of the early engineering works was connected with the River Thames, which, at this period, was, from Richmond to the sea, a shallow estuary in many parts several miles wide, thus submerging large tracts of Kent and Essex. London, as it then existed on the high ground of St. Paul's,

was almost surrounded by swamps, the "*Church on the Fen*" indicating one of them, the "Strand" being a real strand for boats. Here, again, the skill of Vermuyden came well to the fore, and was eventually the means of confining the river and its tributaries, etc., within what is now 300 miles of embankments, thus raising its level, saving much valuable territory, and making it the highway of nations, and the main cause of London's greatness; its population in 1801 being 1,000,000, and in 1901, 6,581,000.

In 1590, the population of this city was 150,000. The drinking water was very scarce, very impure, and the plague frequently broke out, but, with splendid generosity, Sir Hugh Myddelton, a wealthy goldsmith and banker, engineered, at his own cost, a timber built canal, 38 miles long, from Ware, in Hertfordshire, under the title of the "New River." Thus was London, for the first time, supplied with pure water from a distance.

The internal road communications of the country had to be developed, but, strange to say, during the 18th century, the man above all others capable of carrying out such work, was the totally blind *John Metcalf*, who, through his marvellous genius, and under an apparently insurmountable difficulty, did what no one else could perform in the way of making many excellent roads throughout Yorkshire and Lancashire, thereby abolishing the trails and horse-tracks which formerly existed.

Of course bridges had to follow the roads, but these,

for a long time, were rude timber or stone erections. Here, however, *John Rennie's* skill proved invaluable, as some of the fine old bridges throughout the country still abundantly testify, and amongst these is the present London Bridge, which, after costing—with its approaches—£2,000,000, was opened for traffic in 1831. Docks, harbours, mills, etc., also came handy to Mr. Rennie.

A happy idea originated the widening and deepening of ditches and brooks and rivers for water transport, until *James Brindley*, financed by the Duke of Bridgewater, cut the first canal through solid ground. A canal, too, which immensely benefited Lancashire directly, advanced Manchester and Liverpool by leaps and bounds, and, in 1830, was the means of starting into life the Liverpool and Manchester railway, which opened out the prosperity of the nation, and, indeed, of the world at large.

Smeaton, with his Eddystone Lighthouse and other important works; *Telford*, with his bridges, etc., etc.; and others, had a hand in paving the way for the commercial introduction of the steam engine. *Nasmyth*, by means of his steam hammer, made the grandest *hit* ever known, because he alone enabled heavy forge work to be executed successfully. And amongst a galaxy of miscellaneous talent may be mentioned *Richard Roberts*, of Manchester, who made improvements in textile machinery which coined wealth for nations, though *not* for himself.

Nearly all of those named were uneducated men, who conceived their schemes sometimes in a manner almost akin to inspiration. The fire of genius enabled them to perform many wonderful things which, in others, could only have been done by means of long and careful training. Those dauntless heroes of science frequently executed their work in the face of almost overwhelming difficulties, and the severe opposition of people who wished to be left alone with their loved trails, and horse tracks, and ditches, and pack-horse goods traffic, and stage-coach passenger transit, in preference to better methods.

Their *Lives, as Engineers*, were full of romance and deep interest, and it is therefore well that they should be handed down to posterity, by Mr. Smiles, as brilliant examples of those who performed so much in their own simple way. And all the more so, as they individually brought, as it were, their blocks of granite, some of ten tons, twenty tons, thirty tons, and so on, thus gradually building up and consolidating that magnificent and enduring edifice known as Civil Engineering, which has left its mark for all time on the earth's surface.

We have many highly-gifted engineers amongst the *living*, and more of them are springing up. Who can tell in what manner a few of their grand ideas may yet cause the unapplied forces of nature to be beneficially utilised? One thing, at any rate, is certain, and that is, that if, during this century, engineering science is advanced as it was during the last one, marvels piled

upon marvels, now but dimly foreshadowed, or perhaps undreamt of, will no doubt revolutionise everything now before us in hitherto untrodden paths.

A branch of the profession not yet referred to is that *Connected with the Sea*, which many aim at, as the pay, in first-class steamers, is still good, and the treatment excellent. Here, however, a sound practical and theoretical knowledge of engineering, from a ship-propelling point of view, is necessary, chiefly because the machinery of steamers of to-day, especially of the large passenger class, has become so complicated as to require much more vigilance in management than formerly.

The *Duties* that devolve upon the chief engineer of an ocean mail liner, as well as upon his colleagues, are most important and greatly diversified. For instance, in a twin screw 20,000 horse power ocean racer, there are 14 compartments in the double bottom of the hull, having in each case from two to four pumps, the former of which require to be sounded at least twice a day in port, whilst the temperature of the cold storage room has to be taken every four hours in port, and at sea every twelve hours.

The *Ventilation* of the ship, throughout its entire system, involves the application of pipe arrangements with hundreds of openings that, in addition to the following list of pumps and engines in various parts of the vessel, have to be carefully attended to.

The *Machinery*, as a whole, includes two sets of *Main Triple Expansion* engines, each of 10,000 horse power;

two *Pumping* engines immediately connected with the above; twelve *Hydraulic* engines; two *Cold Storage* engines; four *Centrifugal* pumping engines; four *Auxiliary donkey* engines for boilers; eight *Dynamo-working* engines; twelve *Blowing* engines; five *Elevator* engines; six *Pumping* engines in stokehole; two *Pumping* engines in stokehole for *Sanitary* purposes; three *Fresh water* pumping engines, and eight engines directly connected with the *Refrigerating* plant, besides a few more of minor character. Thus giving a grand total of ninety-two single engines of every size, inclusive of all their attachments, and a mazy labyrinth of valves, pipes, rods, levers, etc., that have to be looked after by the engine room staff.

If the engines should be of the very admirable five crank quadruple, 267 pound steam description, burning less than one pound of coal per horse per hour, as built by the Central Marine Engineering Company of West Hartlepool, the engine room supervision will be otherwise distributed. So also will it be if the driving machinery is of the Turbine description, although in all these cases the auxiliary work of the ship remains the same.

The *Chief Engineer* is supplied with an executive numbering 184, assigned as follows:—eighteen assistants for machinery and boilers, three cylinder and two hydraulic experts, and two refrigerator engineers. The rest consist of petty officers, firemen, coal trimmers, etc.

From the above some idea may be gathered of the interior of modern high class liners, and of the skill required, not only in those who work them, but in the designing and constructive staff at the establishments where these vessels are built, and where *everything* is considered from first to last that can in any way add to their safety and efficiency.

The engineers, whose efforts greatly conduce to the successful working of steamships, much resemble—in mind and manner—the navigating officers with whom they are so closely allied. As a class they are extremely varied. Some are highly accomplished—others not so. Some are most courteous and affable—others the reverse. In short, there is to be found amongst those who direct the steam department of ocean liners a set of men whose constant aim, under all circumstances, is to perform their duties at sea and in port faultlessly and happily.

Few, indeed, have any idea of the extreme vigilance required to keep *mail* steamers in perfect condition. When a ship arrives from a long voyage her engines are partially dismantled—that is, the pistons are taken out and examined, so also are the insides of the steam cylinders. The slide, etc., valve faces, their working gear, crank shaft and propeller shaft, connecting rod and all other bearings; the air, circulating, and all other pumps; the boilers and their attachments; and every auxiliary piece of machinery aboard the ship, as well as the screw propellers outside of her, are most carefully

inspected in view of damage sustained through constant and severe wear and tear.

While the ship is in port these movements keep the engine room staff very fully occupied. When, however, everything is replaced, the shore officials make a rigorous survey of everything in motion and at rest throughout the vessel, at the same time passing through their drill the steam and navigating officers, the stewards, stewardesses, crew and firemen, and everyone else, before she is allowed to proceed to sea. In this manner, the safety of the public is insured at all points.

Some engineers stand by the sea all their days. Others try to obtain shore appointments, such as those of Superintending, or Assistant Superintending Engineers to Steamship Companies, whilst a few take voyages merely to gain that unique and useful experience which they cannot acquire in any other way.

As all those at sea work, not by hours as we do, but by "watches" of four hours *on* duty, and four hours *off*, consecutively, the "Dog Watch" was introduced to enable the day and night hands to exchange places. Hence the time from four to eight p.m. is divided into two spaces of two hours, each named after the well known animal, because they were *cur-tailed*.

In an insurance case which was recently tried, the opposing counsel asked an old sailor "At what time of the day the collision occurred?" and was told that it was "about the middle of the first dog watch."

With this in view, the barrister, in summing up the

case, blandly observed: "You can imagine, gentlemen of the jury, the care which was exercised on this occasion, when, as appears from one of the plaintiff's own witnesses, this valuable ship and her cargo, and the lives of the passengers and crew, were entrusted to what, gentlemen?—why, to the *mere watch of a dog!*"

The last phase of *Life as an Engineer* to which I shall refer is that of the *Surveyor*, which, now-a-days, has attained a much more comprehensive position than it formerly had, when the science was frequently practised by men in other professions, to the great disadvantage of those who were trained to it. With the object of abolishing this evil, the Surveyors' Institution, of London, was founded in 1868, and since then has been maintained in such a manner as to have greatly conduced to the welfare of those for whom it was intended.

The Charter of the Institution defines the work of the surveyor as "the art of determining the value of all descriptions of landed and house property, and of the various interests therein; the practice of managing estates; and the science of admeasuring and delineating the physical features of the earth, and of measuring and estimating artificer's work."

To enable students to obtain the best information in any of its branches they may select, courses of preparation have, for many years past, been specially arranged by Mr. Richard Parry, Surveyor and Barrister-at-Law, of 82 Victoria Street, Westminster, which have proved eminently successful. Some idea of the extent of the

range of a surveyor's occupation may be gathered from the fact that, from an engineering point of view alone, students are educated in all the minute details of land surveying and levelling—trigonometry—mensuration—drainage and sanitation—quantity surveying—building surveying—geology and composition of soils—agricultural chemistry—road making, etc. So far as the accomplished railway surveyor is concerned, it may be said that, when engaged on vast enterprises, he has to work for perhaps several consecutive years, under climatic and geographical and other conditions sometimes of an extraordinary nature. When, for instance, he has to cross for hundreds of miles, stupendous mountain ranges under all the vicissitudes of ice and snow, and avalanches, and severe cold and other evils, then it is that all his skill, patience and perseverance are exercised to the utmost.

The first great railway of this nature was the Union Pacific, in the United States, which proved quite an education even for those who considered themselves masters of the art. Said one of them:—"After the road was completed, in many cases it had to be changed to overcome one great obstacle those unacquainted with the country would never dream of—the question of *snow*. We had to study every summit, every mountain side, every valley, to find from the currents which was the snowy side and which the barren; and over the whole 1,500 miles of line located for the Union Pacific, for three winters we kept en-

gineers in tents or dug-outs watching from four to six months the drift of the snow and water to be overcome, and the safest, surest and most effectual methods of doing it."

During the initial movements for the construction of the Panama Canal, the surveyors, whilst traversing dense forests, had to take their theodolites and other instruments with them to the top of giant trees before they could spy out the land sufficiently. All through the surveying operations for the Canadian Pacific Railway, too, these evils were more or less successfully encountered, especially over the 550 miles of lofty mountains which lie between the prairies and Vancouver.

Now, we have another colossal undertaking for the engineer surveyor already in hand, namely, that of the new Trans-Canada line of the Grand Trunk Railway Company, which, for thousands of miles, is to extend from Quebec to the Pacific Coast. Many of the difficulties named are now being experienced by the surveyors, and, additionally, those which arise through unavoidably employing *Indian* guides and helpers, as they are very capricious, superstitious, and sometimes almost unmanageable.

Besides doing their business on the land, railway surveyors have sometimes to do work on the water. That is, for example, to see if it is possible to carry a line on piles for twenty miles or so, across a lake, to avoid a circuitous route of sixty or eighty. They have

also to trust their valuable lives to boats on turbulent rivers, or to single "tree bridges" of the cat traversing order across the same.

When I had the pleasure of meeting, in Montreal, Mr., now Sir Thomas Shaughnessy, President of the C.P.R., he told me that on one occasion Sir William Van Horne and their Engineer-in-Chief were prospecting for the line in a canoe on one of the British Columbian rivers. The Indian pilot they employed was so irregular in his movements that the latter was compelled to ask him if he "knew how to steer his boat, as he wriggled it about so much?" This, however, evoked no reply.

After some more figure of eight navigation, the engineer again broke the silence with:—

"What the divvle do you mean by wasting our valuable time in this absurd manner?" Still no answer.

A few more circumvolutions caused the C.E. to blandly enquire "if any one had been down this river before?" To which the Indian replied: "Yes sir, but—*they're there still.*"

It will thus be seen that the vicissitudes of a railway surveyor's life are not always happy ones, although there is much in them, nevertheless, of a delightful nature.

CHAPTER XXI.

THE FINANCIAL PROSPECTS OF ENGINEERING.

Financial decay of the Professions—*Weeding* operations necessary—The "Living Wage" and "Living Income" compared—*Too old* at Forty—How to act when Stranded—Useful Hints—Value of Hand Tool accomplishments—A New Life in a New Land—Manitoban Lady's letter to the Author—British Aristocracy on the Prairies—Some of their Occupations—Happy Life in the Colonies—The Engineering of Nature—Peculiar experiences of the Author at Home and Abroad—Conclusion.

As the best way of ascertaining the true state of the times in professional and in general business life, I have, for some years past, gathered from people of all ranks much information which clearly indicates that, while some favoured ones prosper greatly, and others only moderately, the "success" of the majority is so contemptible as not to deserve the name, considering the earnest efforts made to obtain it.

The working classes have said much about what they very properly term the "living wage," but do not seem to know that there are multitudes to-day whose perhaps costly education and marked ability, and knowledge, and experience, and prolonged industry, will not enable them to earn even a living income. So far as engineering is concerned this statement is very appro-

priate, owing to its terribly overcrowded condition and other causes which cannot be avoided, the cruellest cut of all, however, being the fact that hardly any one is now considered eligible for vacant appointments if past the age of forty, the blighting, blasting, desolating effect of which is only too apparent, and sometimes most unhappily thrust upon us.

The remedy for such a state of things may be comparatively easy to suggest, but not so easy to adopt, when people are so hard to move out of old grooves. Some might imagine that a change of occupation would be desirable, but this, without strong inducement, would not be judicious. Suppose, however, that from causes over which there is no control, such as serious decay of practice through loss of good clients, or long continued compulsory idleness, etc., your calling eventually strands you, what are you to do?

The best plan seems to be to make the mental and physical training of your original occupation the means of helping you to succeed in another, especially *abroad*, where you may have good reason to expect success in the future. It may further be stated that, with the exception of those who are favourably situated regarding fortune or influence, the rising generation would do well if it avoided the now densely overcrowded professions and clerkships of all kinds, etc., for some years to come, and with an acquired fair knowledge of hand-tool working in wood and iron, aim at a new life in a new land, especially Canada, where, with energy and

intelligence combined, they may rise in time to prosperous positions.

In other words, with the manual accomplishments named, coupled with a desire to obtain advancement in agricultural pursuits, they may build their own houses of timber, make their own fences, till their own land, and, with skilled treatment, induce it eventually to give them the success the Old Country denied. Thus enabling them early to become their own masters, with nice little homes of their own, the glorious love of their good wives, amidst happy surroundings, and the privilege of getting as *old* as they can without loss of value, instead of having perhaps a beggarly income, or none at all, and with the dread expectation of being, in a short time, a miserable, lonely, poverty-stricken castaway, without hope, at the early and prime age of forty!

Love of the Home Land with all its associations, and an unwise dislike to even the idea of a Colonial life will, no doubt, prevent many from adopting this course, but, with our strained business relations, as described, and as they have been so often and so painfully brought before me of late years, what can you do but try for at least some prosperity in the Dominion, which now promises better than any of our other possessions.

To correct those distorted ideas of life abroad, which are unhappily too prevalent, let me here give a few extracts from the letter to myself of a lady who, with her husband, had many years' experience of things Manitoban.

We had, in our part of the country, the sons of three earls. The nephews, nieces, and cousins of earls were almost innumerable. I have heard the niece of a farmer, whose father was a general, and whose brother is an admiral, declare with great pride that, in summer and in winter her week's washing was folded, ironed, and mended all on a Monday, and also that she and her husband had together washed twenty-two blankets in one day! This was Mrs. ——, now of ——.

Another lady, who was accustomed to this work, was Mrs. ——, whose husband was an earl's nephew. She and her husband's sisters had all, I believe, been presented at Court. Our close neighbours were the ——, of Northumberland, and I remember Miss —— coming to my house with a copy of *The Queen* to show me the description of her sister's presentation dress at the Drawing Room. Amongst our other friends were two families who had large legacies left them by English relations. I may add that some years ago the heir to an Irish earldom had to be hunted for on the plains of Manitoba before he could be found.

My own most excellent mother, who was a daughter of an Ayrshire county family, whose father was educated as an advocate, and a relative of many other similar families, put *her* shoulder to the wheel in the Australian Bush, just as people of to-day do in Canada, and often in the Home Land, even to the end of her unusually long life, told me that some of her happiest years were thus spent. Her cares, however, were much lightened by the aid of a ticket-of-leave domestic servant, who was good at everything. The same class of men helped my father on the farm, and did well. These remarks

will show that however much the nobility and gentry may lose caste in the Old Country by the exercise of manual labour to enable them to earn an honest living, they certainly do not do so in the Colonies.

All things considered, it seems that, although in one sense there is no place like home, still, when it refuses to give you even a decent living, through changed times, the best thing to be done is to try, amidst new scenes, to obtain at least a fair share of success otherwise unattainable.

During my special tour in Canada under the kind friendship of many influential people, including the Governor General, I gathered from those I met much useful and interesting information about themselves and their families, and found that in most cases they had come from the British Isles and done well. I hope, therefore, these few observations may be the means of indicating to my readers that it is high time that *something* should be done to avert or to mitigate a state of things which is now so distressing.

As a few final remarks in this volume, let me say, as one who has long and lovingly worked in the field of engineering, and possesses a full appreciation of the great value of the other professions, that I may be excused for considering that just named the most comprehensive of them all, because most of the others are variously indebted to it. It has been quite as fascinating an occupation to myself as it was to many of

the departed "Eminents," who, although sometimes of great age, would not retire from it as they could not lose the mental excitement its practice produces.

Personally speaking, I have long greatly admired the beautiful and highly skilled work of man, some of whose best ideas, however, have been taken from nature, notably, the oar, the paddle-wheel, the screw-propeller, the rudder, and the submerged shape of a boat from the fish, and the hollow column and hollow beam from the bird, and so on. But when I turn to the works of nature around me; to the mechanism of the heavens above me; and to the machinery of the universe in the realms of endless space, I sometimes feel overpowered. Indeed, it is very likely that, if I were an idolater, I would worship the sun, moon, and stars on Sunday, Monday, and Tuesday, and the rest of animate and inanimate nature on the other days of the week.

So far as our planet is concerned, the original moulding of the mountains by volcanic agency; the grooving, channelling, shearing, planing, rupturing, etc., of their sides by the same force, aided by the ancient glaciers; the rending, tearing, and eroding of cyclopean and other cañons; the milling and scooping out of the river beds by ancient floods; the numerous volcanic safety valves which have prevented our globe from being blown to atoms ages ago, and many other visible results of stupendous natural action in the past, have all a charm for me.

I can do much better, however, than worship nature

as described. I can keep myself in touch with the Infinite—with the Great Designer of all things—from day to day, and thus feel practically on the verge of a new world, from which I can draw guidance on the journey of life, and happiness for each day as it comes and goes. This I have experienced for many years, and in many peculiar forms. I have, for example, sometimes been involved in enterprises which promised well, but which would have eventually landed me in financial loss, if—just in time—some friend had not unexpectedly crossed my path; some other accidental circumstance; some flash idea, even a forgotten letter, pointed out the danger into which I was unconsciously drifting.

I went to Canada, as previously mentioned, without any definite idea regarding my movements, and yet, when I reached Montreal, I accidently met three most important people who so enabled me to shape my course from ocean to ocean, and gave me an "open door" throughout the land, that everything fell into line, and caused my mission to become a complete success.

I can go further even than that. In *marriage* I aimed high for all the qualities in a woman which would conduce to happiness for both. Here, however, all my best efforts failed until one day, while sitting beside a valued friend, without any "intentions" whatever, a flash thought from the skies—a sudden inspiration, as it were—pointed her out as the one woman in the world best suited for me, and I for her. In three minutes more we were "fixed up," as the Canadians

say, and within three months we were united, and have been among the happiest of the happy ever since. Thus forcibly reminding me of the well-known quotation:

> There's a Divinity that shapes our ends
> Rough-hew them how we will.

These last experiences I almost refrained from giving, but on second thoughts I fancied that, as one so favoured, I *ought* most gratefully to do so, because their perusal might be useful to some, or at least, point a moral as well as adorn a tale.

This being in touch with—this clinging to—the Infinite in everyday life, with all its cares and anxieties, is a magnificent thing. It makes one feel immortal already. In all the childlike simplicity which some of our greatest men and women have so abundantly possessed, it makes people monarchs of all they survey. It enables them—like the Prisoner of Rome—to tread the earth with a more than conqueror's enthusiasm, and in times of adversity, lifts them out of themselves, and gives strength to the weak, and life to the dead. It is good for the health, and refreshing to the mind, and carries people through all the exigencies of life with a joyous spring, until at last, leaving the land of the dying behind them, they cross the Frontier into the Home of the Living.

All through this volume I have written as simply as possible, preferring rather to *touch* only upon engineering subjects, which, other treatises, including my own—

described at the end—may sufficiently enlarge upon. In continuation of my remarks upon a prospective field for the rising generation, I may well recommend my popular book *3,800 Miles Across Canada*, which has been officially approved in high quarters, as well as by the press and by the public, as the reviews will show.

I have also a number of diversified lime-light lectures which have been delivered throughout the country, a list of which is given at the end. Full particulars of all I shall be very pleased to send on request.

In conclusion, let me thank most heartily all those kind firms and individuals, at home and abroad, who have so generously permitted me to inspect their works, and supplied me with the best and latest information, and also allowed me to use illustrations of their productions, and describe their processes of manufacture. I need not here mention their names as these have already been given in the text, and so the best thing I can now do is to wish them all long life, health, happiness and prosperity in their various undertakings.

The preparation of this book has been a labour of love all through, and if the reader—in its perusal—has had only a small portion of the pleasure the author has possessed while writing it, I shall be happy.

SUPPLEMENTARY CHAPTER

TO

LIFE AS AN ENGINEER.

STEAM, ELECTRIC, GAS,

AND

OIL MOTIVE POWERS COMPARATIVELY CONSIDERED.

BY

J. W. C. HALDANE, C.E., M.INST.MECH.E.,

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"STEAMSHIPS AND THEIR MACHINERY;"

"RAILWAY ENGINEERING—MECHANICAL AND ELECTRICAL;"

"3,800 MILES ACROSS CANADA," ETC.;

AND VARIOUS POPULAR LIMELIGHT LECTURES.

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WITH PLATES.

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LONDON.

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1910.

CHAPTER XXII.

STEAM, ELECTRIC, GAS AND OIL MOTIVE POWERS COMPARATIVELY CONSIDERED.

Steam Motors—Yacht and Launch Machinery—Combined Tandem Quadruple Engines and Boiler for a sixty ton Yacht—Plates of each—Compound Engines of the Present—Improved Triple Expansion Engines — Four Crank Quadruple Expansion— Steam Pressures of 250 to 350 pounds per square inch— Extreme lightness in Machinery—Its working Dangers exemplified—A safe Rule—Warship saved from total loss by her Engines—Utilisation of *Waste* Products—Notable Examples— New use for Waste Steam – Combined Reciprocating Engines, and Low Pressure Turbines—Wonderful Economy—Valuable recent Inventions—Story of the Boilers—Master Stroke in Waste Heat Economy — Incidental Advantages — *Electric* Motors—*Aerial* Machinery—Flash Light from the Past upon the Future—*Electrical* Marine Engines—*Gas* Marine Engines— Success on a Large Scale—*Oil* Marine, &c., Engines—Comparative Advantages of Steam, Gas, and Oil in Practice— Tables of Comparison for each Motor—A New Tractor— Safety of Crude Petroleum during a vast Conflagration—New Works for constructing Oil, &c., Engined Vessels—An Amphibious Motor Car—Projected Revolution in Locomotive Building – Concluding Remarks.

THE volume to which this supplementary chapter is attached, so describes *Life as an Engineer* amongst the usually diversified and powerful classes of machinery, etc., that, owing to the growing importance of those which form the motive powers of launches, yachts, and

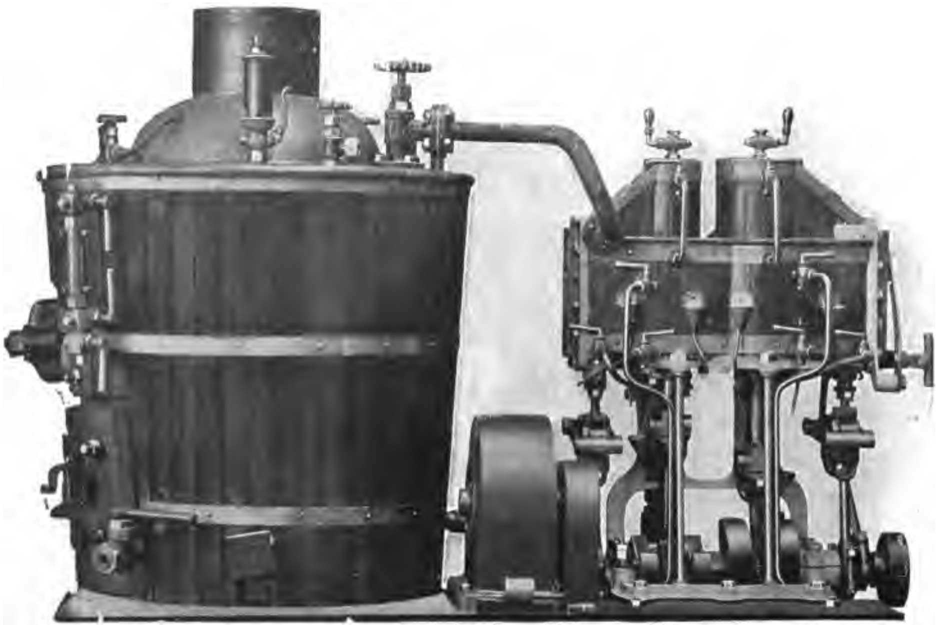
other small vessels, and also of increased economy in coal consumption, I have been induced to write on these subjects, and others of kindred nature.

The powers just mentioned include steam, electricity, gas, and oil, the mechanical arrangements of which have been so much improved of late that I have necessarily drawn my information from various eminent firms and individuals who have recently spent much time, trouble, and expense in trying to perfect them.

The *Steam Motor* is naturally the first that rises to view, both itself and its boilers having been so altered and amended within my own memory, that it seems as if finality in this direction had been nearly reached.

In illustration of this, let me here describe a very popular class of machinery manufactured by Messrs. Simpson, Strickland & Co., of Dartmouth, chiefly for the vessels named, which is shown in the plate opposite, of a set of *Kingdon's Patent Tandem Quadruple Engines and Boiler*, for a 60 ton yacht. These are remarkable for compactness, economy in construction and in working, and also extreme simplicity of design.

The next plate gives an *Outside View of the Yacht*, showing her deck gear, funnel, masts, sails, &c., the *Half Deck Plan* below, and *Half Sectional Plan*, showing the space occupied by the engines, boiler, coal bunkers, also the general arrangements of cabins, etc., which explain the rest. The indicated horse power of the engines is about 140, at 175 pounds working pressure, the diameter of steam cylinders, $8\frac{1}{2}''$, $11''$, $15''$, and $20''$,



KINGDON QUADRUPLE ENGINE, AND KINGDON PATENT BOILER.

and the stroke of piston, 11″, the speed of the ship being $10\frac{1}{2}$ knots, or 12 miles an hour.

These engines may be variously modified. For instance, if we suppose the two top cylinders removed, we shall then have a good example of the *Compound Engine*, which is the simplest and cheapest, and is extensively used, especially by the Admiralty, and for commercial work. It is easier to handle than Triples or Quadruples of the same power, but requires a larger boiler and greater consumption of coal. Owing, also, to the difficulty of accurately balancing a two crank engine, it is not so suitable for high speeds. The air and feed pumps are driven from one of the piston rod crossheads by means of the usual levers, but when the speed is too high for this purpose, worm wheel reducing gear, driven by the main shaft, is employed instead. In a new design by the builders, the machinery is enclosed in an oil tight casing, within which the self lubrication is so perfect as to require hardly any attention.

By dispensing with the smallest cylinder, and placing the larger of the top cylinders next the boiler, and adding another crank to the main shaft, we have the *Triple Expansion* type, which is the most popular, as the extra coal-saving properties of the quadruples are not generally considered sufficient to counter-balance their inherent practical disadvantages. In yacht engines of the above type so many improvements have been made that they can now run at very high velocities without heating, or undue wear of the working parts. Careful

experiments have shown that these engines require about 25 per cent. less steam, and, therefore, a smaller boiler and coal space than the two crank compounds referred to, and are well adapted for water tube boilers working at 250 pounds per square inch, illustrations, etc., of which are given on pages 94, 100, and 290.

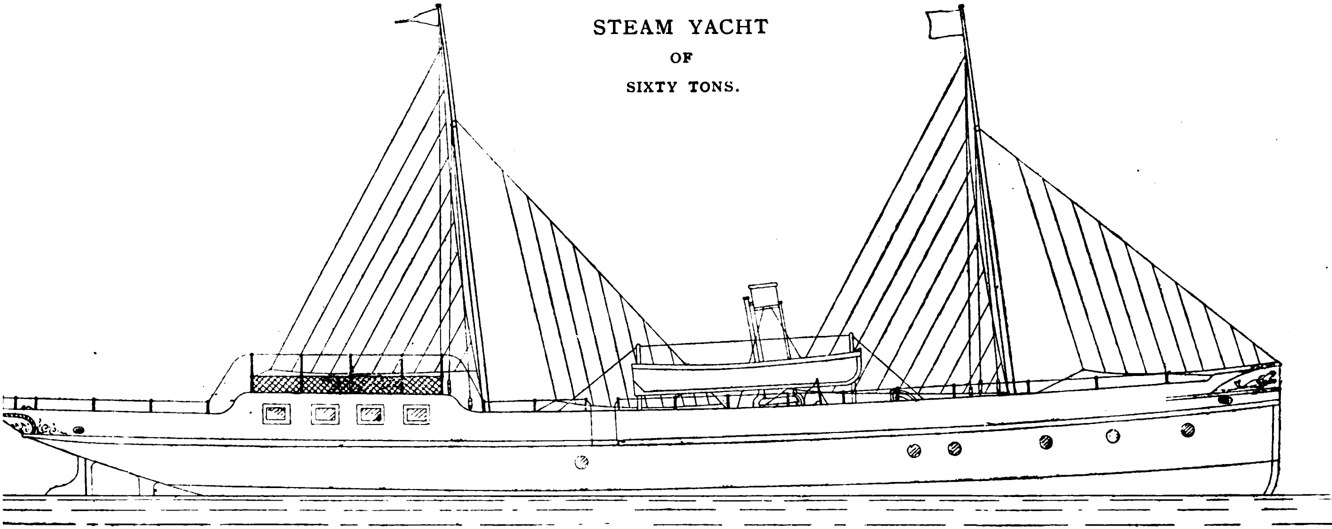
If, now, we suppose the smaller of the two top cylinders placed in a fore and aft line with the lower ones, and another crank added, we shall have a good example of a *Four Crank Quadruple Expansion* set of machinery which has long proved extraordinarily successful, owing to its perfect balance at high speeds. For instance, a set of this class, of 350 horse power, was run at 700 to 900 revolutions per minute, for three seasons, without requiring any repairs or adjustments beyond a new set of piston rings, the special arrangement of cylinders and cranks regarding each other, and only two sets of valve gear controlling the whole of the machinery, having conduced to bring about this result.

The standard types of these engines are designed for 350 pounds boiler pressure, but, if required, they can be made to suit lower pressures. For racing purposes they may be built not to exceed 20 pounds weight per horse power, ready to start; but for ordinary cruising, where no special attention is paid to extreme lightness, about 30 pounds is allowed. Under all circumstances, however, the builders of naval and mercantile ships of all sizes, carefully design every detail so as to have the

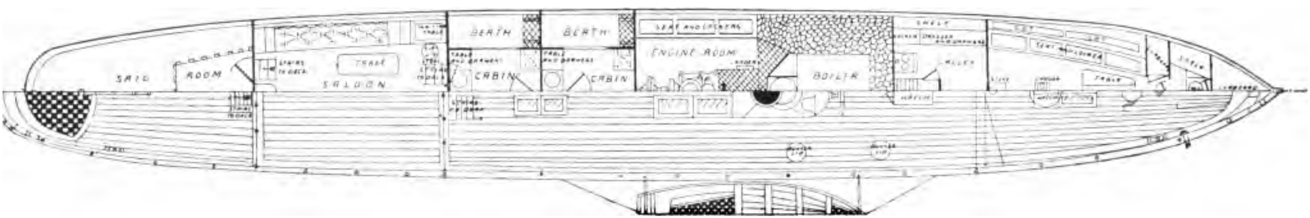
STEAM YACHT

OF

SIXTY TONS.



SIDE VIEW.



HALF SECTIONAL PLAN, AND HALF DECK PLAN.

greatest strength with the least amount of material consistent with perfect safety. It is very regrettable, nevertheless, that extreme lightness should sometimes be demanded in face of a heavy penalty two illustrations of which, amongst others, rise to view.

Some time ago, the Admiralty gave to several eminent firms a number of small vessels to build, under a penalty of £1,000 if their machinery exceeded a certain weight. The engineering director of one of these firms, foreseeing danger which could be avoided, made the engines a little heavier to suit his own experience. Well, the ships were all delivered in time, and tried at sea under the most rigid conditions, and my good friend's vessel was about the only one which did *not* breakdown in some way or other. I call him "my good friend," because, previously, I had the honour of being on his designing staff for some years, and well knew his methods of doing things.

I also remember a fatal disaster that occurred on the East Coast through extreme lightness of parts. A torpedo boat by a famous firm snapped an important detail while running full speed on trial, and caused a smash by means of which several lives were lost.

The only safe rule is to let *Theory hold the light, while Practice does the work*, make everything a little stronger than strong enough, and, to that, add as much more strength as the matured experience of the designer considers necessary to meet the terrific strains which may arise during a storm, possibly off a lee coast, when

even a small failure may cause the loss of the ship and all on board. Just one example:—

Some time ago, H.M.S. *Calliope* lay at anchor with other warships in Samoa Harbour, when an awful hurricane arose, and swept ship after ship upon the rocks. The *Calliope*, however, raised her steam to its highest pressure, and, then, with the engines racing to their utmost, she slipped her cable and stood out to sea, her *bronze* propeller just gaining the extra half knot an hour of speed which saved her, as she forged ahead amidst the cheers of the doomed crews in the remaining British and American vessels!

The Utilisation of Waste Products is a subject of the highest importance in every sense of the term, and of this we have very many striking examples. For instance, a holiday visitor to Liverpool accidentally discovered a bale of "useless" hair just on the point of being returned to Peru. With the owner's permission, he took a little of it home with him for experimental purposes, which led eventually to the very extensive manufacture of *Alpaca*, through the genius of Mr.—afterwards Sir—Titus Salt, of Saltaire.

The discovery that some filthy refuse could be turned into *Velveteen* was a master-stroke of Mr.—afterwards Lord—Lister, of the great and very prosperous Manningham Mills, of Bradford. And who can estimate the immense benefits which have been derived from the invention of Refrigerating machinery, which

preserved for world-wide use the *waste beef* which, in my young days in Australia, was thrown away, after the hides, horns, and tallow had been extracted.

Now, we are entering upon a New Era with steam. In Newcomen's engine of 1720, the *Waste Steam* was most extravagantly and perniciously treated through being condensed *inside* the steam cylinder. The separate jet condenser of James Watt, in 1765, was a splendid stroke of design. So, also, was Hall's surface condenser, of say, 1850, both of which were long universally employed. Recently, however, through a valuable discovery of Professor Rateau, of Paris, all the waste steam of high pressure and also condensing engines and steam hammers, can be re-used, and thus effect a great saving of coal. Mr. P. J. Mitchell, of Caxton House, Westminster, London, has kindly explained to me the working of this apparatus, a description of which would be too technical for any ordinary reader, and therefore I must confine myself to mere facts and *results*, which, after all, are the most convincing.

It is well known that the reversing rolling mill, and winding engines, and steam hammers, are very wasteful of steam, but how to obviate this enormous loss of energy has baffled the scientists for about seventy years. Now, however, the learned professor, of steam turbine fame, has solved the problem by collecting the heat contained in the exhaust steam from intermittently running engines, such as the above, and others as well, thus giving a constant supply of waste steam for use in

specially arranged low pressure turbines of his own design. This idea dates back to 1840, when it was patented by Messrs. Corde & Locke, but it could not be perfectly utilised until the invention of the *Heat Accumulator* by Professor Rateau.

This may be gathered from the fact that, although Mr. Mitchell only introduced it into this country in 1904, at the works of the Steel Company of Scotland, in Glasgow, he has since supplied it to many of the other great establishments, including the Cleveland Iron and Steel Works of Messrs. Bolckow, Vaughan & Co. The best expectations of this firm have been surpassed. As the instalment of three exhaust steam turbines has caused them to dispense with *twelve* coal burning boilers, and *sixteen* gas fired boilers, 125 tons of coal per day have been saved; but when the extensions to this plant are completed, the annual saving in fuel will amount to between £50,000 and £60,000.

These turbines are of the mixed pressure type, that is, they are fed nominally by exhaust steam, and in case this is at any time insufficient, the necessary quantity of live steam can be automatically and correctly added to it. The apparatus has also, for some time past, been employed by many large Continental works, in the United States, and in Canada, where the immense establishment of the Dominion Iron and Steel Company, at Sydney, Cape Breton, will shortly be using it to similar advantage.

The success of the above machinery is largely due to

the complete manner in which a high vacuum is maintained in the condenser, which, at Messrs. Wilsons, Pease & Company's Tees Iron Works, has amounted to as much as 29·6 inches. For a long period a suitably effective air pump could not be obtained, until M. Maurice Leblanc of Paris, took the matter up, and invented a valveless *Rotary Pump*, which is remarkable alike for simplicity, efficiency, and novelty, the old system of *jet* condensation, in unique form, being part of the arrangement. This pump is also suitable for ordinary surface condensers.

In connection with the above appliances, it may be said that the low pressure turbine occupies a territory for the conversion of waste heat into useful energy, which cannot be appropriated by any other form of heat motor. The practical conclusion is, therefore, that the combination of the ordinary simple reversing engines with low pressure turbines will return more power for a given weight of steam than any system of compounding such engines can possibly afford, by allowing the waste steam to pass to the ordinary condenser.

On 20th January, 1908, a valuable paper entitled, *The Development of the Rateau Patent of Exhaust Steam Utilisation*, was read by Mr. Mitchell before the Cleveland Institution of Engineers, passing of course through the usual keen discussion of experts, some of whose remarks clearly indicated that there is a great future for an invention which has already shewn its power to economise working expenses on a great scale. Indeed,

one of the speakers anticipated that, in a few years, we should have by its use, in this country alone, a saving of many *millions* of tons of coal per annum.

For some of the great ocean liners, too, including the White Star-Dominion triple screw R.M.S. *Laurentic*, of 15,000 tons, and 21 knot speed there seems to be a bright prospect. Here, steam from the main boilers is first used in the two sets of triple expansion engines, and then passed on to a low pressure turbine on another shaft, thus effecting a considerable saving in coal, in weight, and in space.

Nothing more clearly indicates the success which has crowned the efforts of many in the field of fuel economy during the last century, than the fact that in 1825, our coasting steamers burnt *10 pounds* of coal per indicated horse power per hour; and, in 1900, the s.s. *Inchdune* and *Inchmarlo*, built by the Central Marine Engineering Company of West Hartlepool, consumed only *one pound*. The engines of these ships were of the quadruple expansion five crank type, and the steam pressure 267 pounds per square inch.

Few, except engineers, can have any idea of the patience and perseverance, and the talent exercised by those who won their way amidst many difficulties, and disappointments, and losses to eventual prosperity in this direction. The *Story of the Boilers* bristles with romance, but, very briefly sketched, it is as follows:—

The box-shaped flue boilers of 1825, for 15 pound pressure ordinary engines, were superseded by the

tubular boilers of 20 to 25 pounds amongst the "fifties." Then came the compound engine at the end of the same decade, with cylindrical boilers of 60 to 90 pounds pressure. Next came the triples and quadruples, with steam from 150 to 300 pounds, in water-tube boilers, which was incidentally necessitated by improvements in the engines which allowed the steam to be expanded more and more as it passed from cylinder to cylinder, many structural and chemical innovations having unitedly helped to reduce a ship's coal expenditure.

The invention, however, which has *externally* most benefited steam producers on land is the *Economiser* of Messrs. E. Green & Son, of Wakefield, which, in the simplest and most effective manner, utilises the *waste* heat from the flues before it goes up the chimney. This is accomplished by placing a number of vertical tubes across the main flue, thus heating the feed water contained in them to at least 300°.

As a result of this, the boilers are saved from the evil effects of unequal expansion and contraction ; their water is purified ; their steaming capacity increased ; their life prolonged, and 15 to 25 per cent. of coal is saved.

It may be added that since the year 1850 to the present, nearly 230,000 boilers have been supplied with these Economisers, now much improved, and that the works in which they are manufactured have recently been enlarged and completely remodelled throughout.

When we consider that *Electricity* has been within

man's reach ever since the Creation, it is amazing that it is only recently that it has been practically employed. So rapidly, too, that judging the future by the past, it may be said that we are only at the beginning of a tremendous transformation scene on land and sea, which will surpass the wildest dreams of the most devoted enthusiast in the field of Science.

Before wireless telegraphy came into use, it seemed impossible to convey electrical messages by any other means than by something tangible—something to be seen, and felt, and handled, perhaps killed by if touched. And yet this apparently impossible aerial flight of information has become a constant occurrence across oceans, and mountains, and valleys for thousands of miles, simply by means of a fiercely concentrated rippling of the air—as on a pond by a discharged stone—between two far distant stations on land, or between ships at sea.

Much has been done of late towards perfecting the *Flying Machine*; and the application of electricity as a motive power to the most extensive works, and the most colossal machinery. As, however, we have seen a few "hairbrained," "idiotic," "madcap," etc., schemes carried safely and beneficially through, we have reason to believe that, later on, we shall be able to draw electricity from the air without the aid of machinery of any kind. When this is accomplished, the aerial machine will be perfected, and we, individually, will be able to *fly* with ease whenever we wish to do so, much in the same way as the angelic beings with whom we

have had a life-long pictorial association. Of course, many will consider this idea "fantastic," "unpractical," "ridiculously absurd," and so on. Well, wait and see.

As Chapter XIX contains much concerning this wondrous Force of Nature, to which I need not again refer, it may be said that since Professor Faraday made his great initial discovery in 1831, many other minds have been engaged in improving this branch of engineering, and to their innovations are due all that we have around us to-day. Not much, however, has yet been done towards the electrical propulsion of ships, but a large field has been opened out for it in small vessels, such as lake, river, etc., launches for pleasure and other purposes, and in this respect it has proved a beautifully clean, simple, space providing, and highly successful means of transport.

Here, a number of Electric Power Storage Company's Accumulators in teak-boxes, are conveniently placed, either under the deck of a yacht, or beneath the seats of a boat, for driving the motor which, in the most compact manner, actuates the Screw Propeller, only, however, for a limited period, as the accumulators can be re-charged when necessary. By this means, a launch filled with ladies and gentlemen in Hyde Park costume for a hot day, can have a delightful trip, under the happiest conditions.

The Plate at page 300, shows an improved *Dynamo*, which, stripped of the driving pulley and outer support, will give a good idea of a simple motor, adaptable, with

small modifications, for any purpose, including that just named.

When the Otto and Langen *Gas Engine* came out in 1866, it was the rudest, roughest and noisiest piece of mechanism I had ever seen. So much attention, however, has since been continuously bestowed upon it by a host of talented improvers, that, nowhere is there now to be found an engine that can run more smoothly, or more effectively, up to, say, 6,000 horse power.

At page 294, a plate representing a *Combined Suction Gas Producer and Gas Engine* will give a good idea of this motor, the economy of which, and its special value for intermittent work, are extraordinary. This is largely due to the utilisation of the waste gases of blast furnaces, and in other ways upon which the late Mr. B. H. Thwaite, C.E., bestowed so many of his best thoughts, and whose publications are very instructive.

So far as ship propulsion is concerned, the *Gas Marine Engine* has done well. Its future development, however, is in the hands of many eminent firms, including Messrs. Vickers, Sons & Maxim, Messrs. Beardmore & Co., Messrs. Thornycroft, and others, who have for some time past experimented with and built a number of gas driven, or gas and oil propelled, naval and commercial vessels with much success.

Mr. James McKechnie, the engineering director of the Barrow Works of Messrs. Vickers, after some years

of continuous researches, and the construction of 40,000 horse power of marine gas engines, informs me that they have at last adopted a satisfactory two-stroke cycle gas engine which may be worked either by producer gas, heavy oil, or compressed air, and may be made as easily reversible as the steam or compressed air engine. It is also possible to use it in conjunction with pressure gas generators, which deliver their contents direct to the engines. The change from gas to oil can be almost instantaneous, and an important feature of the arrangement is that in battleships, or other large ships, the coal may be stored in the bunkers, and the oil in the double bottom—a duplication which is always desirable. With oil, too, the engines may be started *when cold* within a few minutes.

For the above important facts I am indebted to an illustrated paper entitled *The Influence of Machinery on the Gun Power of modern Warships*, read by Mr. McKechnie before the Institution of Naval Architects in March, 1907. From this paper I take the following Table, giving the comparative weights, area occupied, fuel consumption, etc., of steam, gas, and oil machinery for a 16,000 indicated horse power battleship.

The advantages claimed for the gas marine engine chiefly consist of:—

Half the amount of fuel compared with steam.
Stand-by losses reduced fully 75 per cent.

The disadvantages of steam boilers completely dispensed with.

Working pressure confined only to the *engine* cylinders.

No condenser vacuum necessary.

Reduction of weight and space occupied by gas engines and producers, as compared with steam engines and boilers.

Easy firing and stoking, as the producers may be charged only once in every twelve hours.

The gas producer makes its own motive power at about atmospheric pressure.

Much less liability to break down, etc.

COMPARISON OF WEIGHTS, &c.	STEAM.	GAS.	OIL.
I.H.P. available for propelling Ship	16,000	16,000	16,000
Weight of Machinery, including Auxiliary Engines, but not deck Machinery	*1,585 tons	†1,105 tons	‡750 tons
I.H.P. per ton of Machinery	10·1	14·48	21·33
Area occupied by Main Engines and Boilers, or Producers	7,520 sq. ft.	5,850 sq. ft.	4,110 sq. ft.
Area per Indicated horse power	·453 sq. ft.	·366 sq. ft.	·257 sq. ft.
Fuel consumption in pounds per I.H.P. per hour, at full power ..	1·6	1·0	·6
At about ½ full power ..	1·66	1·15	·75

* Includes water in boilers. ‡ Includes water in jackets and piping.
† Includes water in jackets and piping, but not coal in producers.

I am indebted to a most instructive article by Mr. Vennell Coster, M.Inst., Mech.E., in the "Gas Power Number" of *Cassier's Magazine*. Also for much information regarding the *Gas Marine, etc., Plant* manufactured by his firm, Messrs. Crossley Brothers, of Manchester, including a most useful, interesting, and well illustrated Paper, entitled: "*Marine Gas Propulsion in relation to Imperial Commerce and Defence*," which he read on 26th January, 1907, before the Manchester Association of Engineers. Also working drawings, etc., showing the application of the plant to ships. As Mr. Coster had 18 years' experience with the marine engine, including three years at sea with the Peninsular and Oriental Company, and eleven years with Messrs. Crossley, we have enough to indicate his practical intimacy with his subject.

Engineers of steamships are waking up to the possibilities of this new method of propulsion, which will not only increase the efficieney of their vessels, but ease their own arduous labours. I have the honour of knowing many of my learned brethren of the sea, who have much appreciated what I have said in my books upon *their* branch of Science, to which I have devoted the best years of my life, in various works, and as a consulting engineer since 1873. Taking, therefore, an all round view of the situation, I am certain that, by the time the *Gas Marine Engine* is perfected, it will more than satisfy those who will work it in the future. And, judging by the increasing number of "eminents"

who are bending their best energies to this "most absorbing" subject, it seems likely that before long the new motive power will be well established at sea.

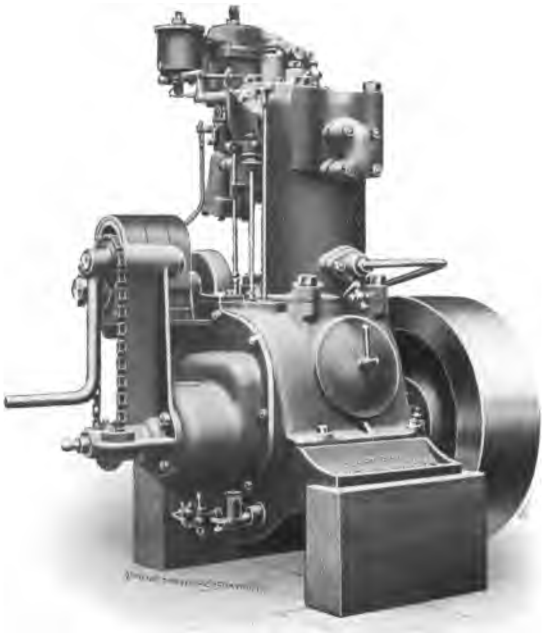
The following table which has been kindly supplied by Mr. A. Basil Wilson, M.I.C.E., of Belfast, shows the difference between the steam-driven and gas-driven sets of engines, each of 2,360 horse power, as proposed for the cargo ship *Lord Antrim*, of 4,268 tons, built by Messrs. Workman, Clark & Co., of Belfast, for the Irish Shipowners' Company. The gas engines being designed by Mr. Coster.

STEAM INSTALLATION IN S.S. *LORD ANTRIM*.

Number of Engines	One Triple Expansion.
Number of Boilers	Two 15 ft. 6 in dia. × 11 ft. 6 in. Steam pressure, 180 lbs.
Diameter of Cylinders.. ..	26 in., 43 in., and 72 in.
Stroke of Piston	48 in.
Speed, knots per hour	12·4 knots.
Total radius of action	9,510 knots.
Donkey Boiler	One 11 ft. 6 in. × 9 ft. 6 in. at 90 lbs.
Number of Propellers	One 17 ft. 6 in. diameter, and 19 ft. 3 in. pitch.
Revolutions per minute ..	67.
Displacement at sea, loaded	9,758 tons.

GAS INSTALLATION IN G.S. *LORD ANTRIM*.

Number of Engines	Three Single Acting, six Cylinder.
Number of Plants	Four, Suction.
Diameter of Cylinders	21 in.
Stroke of Piston	24 in., 350 lbs. Explosion Pressure.
Estimated knots per hour ..	14·26.



HIGH SPEED VERTICAL MARINE GAS ENGINE—SINGLE CYLINDER.

HIGH SPEED VERTICAL MARINE OR LAND GAS ENGINE—DOUBLE CYLINDER.

Total radius of action	16,826 knots.
Auxiliary Producer	30 I.H.P.
Number of Propellers	Five, 11 ft. and 8 ft. diameter, with 15% Higher Efficiency.
Revolutions per minute ..	150.
Displacement at sea, loaded	9,758 tons.

The views on the adjacent plate illustrate *Single Cylinder* and also *Two Cylinder types of Gas Engines*, which have been extensively used for marine purposes by Messrs. Crossley. The left hand view indicates a class whose bed plates are best suited for the keelson fixings of a boat or ship, while the *two* cylinder engines are equally well suited for land or for marine purposes, according to requirements. They are worked alike by petrol, alcohol, paraffin, oil gas, town gas, producer gas, etc. They are also made in the following classes:—Stationary, portable, marine, and electric lighting, from one horse power, as shown, up to 1,000 in one set of three or more cylinders in a row; there can be no difficulty, however, in fitting ships with this class of machinery up to 50,000 horse power.

The following table shows at a glance some of the main points of comparison between a 1,400 horse power steam plant and a similar gas plant for an ocean vessel.

1,400 I.H.P. STEAM PLANT.

1·5 lb. Coal per I.H.P. per hour	=	22 5 tons per day.
300 Days' Steaming	=	6,750 tons.
Cost of Fuel at 10/-	=	£3,375.
Total weight of Machinery	=	373 tons.

1,400 I.H.P. GAS PLANT.

1 lb. Coal per I.H.P. per hour	=	15 tons per day.
300 Days' Steaming	=	4.500 tons.
Saving over Steam	=	2,250 tons.
Cost of Fuel at 6/-	=	£1,350
Saving over Steam	=	£2,025.
Saving of over 5 % on ship costing		£40,000.
Total weight of Machinery	=	267 tons.

Messrs. Yarrow & Co., now of Glasgow, have kindly supplied us with the following comparative particulars of gas and steam torpedo boats, built by them, which will still further throw light on this subject:—

YARROW-NAPIER TORPEDO BOAT WITH INTERNAL COMBUSTION ENGINES.

Length = 60 feet.
Beam = 9 feet.
Speed, light, 25½ knots.
Speed with 3 tons, 24 knots.
Radius of action at full speed, 250 miles.
Fuel capacity, 1 ton.
Lifting weight for transport by rail, 8 tons.

YARROW TORPEDO BOAT WITH STEAM MACHINERY.

Length = 60 feet.
Beam = 9 feet.
Speed, light, 19½ knots.
Speed with 3 tons, 18 knots.
Radius of action at full speed, 108 miles.
Fuel capacity, 2 tons.
Lifting weight for transport by rail, 12 tons.

As a further indication of the forthcoming enormous development of gas power in engineering, it may be mentioned that, only recently, the South Staffordshire Mines Drainage Commissioners satisfactorily replaced

steam engines by *gas engines* in five of their pumping stations. And that a paper entitled *An Internal Combustion Pump, and other Applications of a New Principle*, was read by Mr. Herbert A. Humphrey, M.I.Mech.E., before the Institution, on 19th November, 1909. To this I need only refer my readers who wish elaborate and useful information about pumping machinery thus designed.

The conditions of the *Competition for Military Tractors* held by the War Office at Aldershot, from the 1st to the 14th of March, 1909, were essentially of a nature which called for a vehicle of a unique description, and their exceptional severity may be judged by the fact that out of eleven entries of specially constructed vehicles, only three actually took part in the trials. Of these, the Thornycroft Tractor won the prize of £750, and has since been acquired by the War Office.

Although the weather was very severe, the conditions of the contest were considerably more than fulfilled, either in *weight* of the machine, or *weight of load*, or *speed* to be attained, or *distance* to be run over rough ground, of various kinds, without replenishing the ordinary paraffin oil fuel which was used. This vehicle has therefore proved itself the only one in existence suitable for the purpose named, as well as being very useful for ordinary commercial traction at home or abroad.

Oil or Petrol Motors are frequently used for the same

purposes as gas engines, which they much resemble, the main difference being that the former are driven by petroleum, etc., instead of gas. The oil is stored in an adjacent tank, the supply of which to the engine is first vaporised and then exploded in the cylinder, the crank and main shaft being actuated as in the steam engine. There are many kinds of excellent oil engines in use, one of which, of novel construction, is that of the *Diesel Engine Company*, of London, who have designed a new type for marine purposes, the main advantages of which are as follows:—

Cheapness and abundance of fuel used.
Extreme safety.
Lowest cost of power.
Highest thermal efficiency.
Absence of heaters or vaporisers.
Absence of igniting devices of any kind.
Small space occupied.

In illustration of the above remarks upon gas and oil engines as a whole, I cannot do better than again refer the reader to the plate at page 294, which shows one of the most successful land types of this class of machinery. A class, too, which chiefly owes its selection to the relative local values and convenient application of gas and oil, which are sometimes more weighty than mere super-excellence of each engine individually. At any rate, the great usefulness of the latter, from an all round point of view, may be realised from the fact that it may be employed equally well on a mountain

top, or in the deepest mine, so long as barrels of oil can reach it.

So far as the *mere safety* of *crude petroleum* as fuel is concerned, the Fire Marshal of San Francisco has stated that the remains of the recent vast conflagration have shown that, while nearly every business building in the city had been equipped for oil fuel, there was not one proved instance where oil was responsible for fire. Further, so great has its safety been shown, that it will be *exclusively* used in the new city, crude petroleum being considered the ideal fuel.

Sir John Thornycroft is one of those tireless workers who have well climbed to fame and honour in the field of engineering. He has invented special types of screw propellers, water-tube boilers, and marine steam, oil, and gas engines; all of which have been so appreciated that he has recently erected new works at Southampton and Basingstoke. In these establishments torpedo boat destroyers up to a speed of 35·67 knots per hour, launches, submarine boats, life boats, racing boats, yachts, and shallow-draught vessels are built and supplied with the above oil motors.

Mr. John E. Thornycroft read two very practical and instructive papers before the Institution of Naval Architects, on 24th March, 1904, and 5th April, 1906. The former is entitled *Advantages of Gas and Oil Engines for Marine Propulsion*, and the latter, *Gas Engines for Ship Propulsion*, both of which will greatly aid those who desire authoritative information on this subject.

As the *cost* of machinery has been reduced, it may be mentioned that this is chiefly due to improved design of details on the one hand, and to special machines and tools for facilitating construction on the other. I am, therefore, the more pleased that some of these have already been illustrated and described throughout this book, in some cases presenting a striking contrast to those of only a few years ago.

The *Art of Forging*, in *iron* and *steel* I mean, has been so greatly improved that many thousands of engine, etc., details, up to 120 pounds weight, can now be steam stamped in a rapid, inexpensive, and widely appreciated manner by means of special machinery in the previously mentioned Works of the Central Marine Engineering Company of West Hartlepool. Weldless steel tubes, and chains, too, of enormous strength, are amongst the number of things that are manufactured in great quantities and in wondrous fashion.

Similarly, the *Motor Car* industry, which has recently attained colossal proportions, has also been greatly benefited by special machinery, one of the most astonishing examples of which is to be found in the new Works of the Daimler Company in Coventry. Works, too, which, like others I have named, are splendid studies for embryo "*Eminents*" as well as others.

Another very notable example of improved *Motor Vehicles* is one by M. Ravailler, of amphibious nature, which has recently been accepted by the French government for military or other purposes. The boat-shaped

carriage runs on four wheels driven by an oil engine, which can at once be used for screw propulsion when afloat, or *vice versa*, a bank of 40° being easily ascended with four men on board.

Amongst the various sources of special *technical* information mentioned in this chapter is an excellent and illustrated paper entitled *The Nürnberg Gas Engine*, which was read on 6th February, 1909, by Mr. Richard Bechtel, of the Lilleshall Company, Oakengates, Shropshire, before the Birmingham Association of Mechanical Engineers. This engine represents the best practice of an engineering firm which has immense works at Nürnberg and Augsberg, in Germany, and whose engines, up to 6,000 horse power, are very popular.

Many grand movements are in prospect for engineering. One of which, in progress, is the building of the new White Star R.M.S. *Olympic* and *Titanic* by Messrs. Harland & Wolff, each of which will have a displacement of 45,000 tons, and machinery similar to the *Laurentic*. The Victorian Era has produced many wonderful advances in science. The rise and development of steam navigation—similarly of the railway system, and of manufactures in 100,001 different forms, all testify to this.

One of the latest movements of this nature is an experimental locomotive being built by the North British Locomotive Company, of Glasgow, on the "Reid-Ramsay" system, after many costly experiments,

for express passenger traffic. In this engine, steam is generated in the ordinary boiler, and led to a turbine running at 3,000 revolutions a minute. To this turbine is coupled a dynamo which supplies electrical energy to the four diiving axles, the exhaust steam being condensed and returned to the boiler again and again. The above is an attempt to solve the problem of providing *self-generating electric* engines which could run unrestrictedly over all lines without any special preparations being made for them, and prove more economical in the consumption of fuel and water than in the case of the present engines.

I now conclude this Chapter in the hope that what it contains will indicate alike to all the boundless nature of engineering science—its fascinating influence upon ambitious practitioners—and, so far as *Life as an Engineer* is concerned, furnish useful hints to those who hope to enter it, or are actually in it, and also a warning to those intending to enter such a strenuous profession without being adapted for it.

Since the remarks were made concerning the Humphrey *Internal Combustion Pump*—on page 23—I have learnt that Professor W. Cawthorne Unwin has exhaustively and very successfully experimented upon its general working and fuel economising powers. Thus adding considerably to the commercial importance and application of this extremely simple and valuable invention.

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